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Transmitted herewith for filing is the Patent application of Inventor: S : Kazuhiro OTSUKA, Tsutomu HORIKOSHI,
Satoshi SUZUKI
For METHOD AND EQUIPMENT FOR EXTRACTING IMAGE FEATURES FROM IMAGE SEQUENCE

Enclosed are:

☒ Twenty-Eight (28)
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X PRELIMINARY AMENDMENT

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants : Kazuhiro OTSUKA et al.
Serial No. : To Be Assigned
Filed : Herewith
For : METHOD AND EQUIPMENT FOR EXTRACTING IMAGE
FEATURES FROM IMAGE SEQUENCE

Assistant Commissioner for Patents
Washington, D.C. 20231

PRELIMINARY AMENDMENT

S I R :

IN THE CLAIMS:

Please amend the following claims:

Claim 18, lines 1 and 2, cancel "any of claims 1, 2, 3, 8, 10 and 13," and insert --claim 1,--;

Claim 19, lines 1 and 2, cancel "any of claims 2, 3, 8 and 10," and insert --claim 2,--;

Claim 37, lines 1 and 2, cancel "any of claims 20, 21, 22, 27, 29 and 32," and insert --claim 20,--;

Claim 38, lines 1 and 2, cancel "any of claims 21, 22, 23 and 29," and insert --claim 21,--;

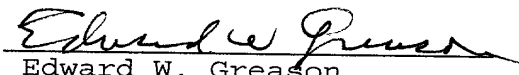
Claim 56, line 2, cancel "any of claims 39, 40, 41, 46, 48 and 51," and insert --claim 39,--; and

Claim 57, line 2, cancel "any of claims 40, 41, 42, 46 and 48," and insert --claim 40,--.

REMARKS

The above claim amendments have been made in order to eliminate multiple dependency.

Respectfully submitted,
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1 TITLE OF THE INVENTION

METHOD AND EQUIPMENT FOR EXTRACTING IMAGE
FEATURES FROM IMAGE SEQUENCE

5 BACKGROUND OF THE INVENTION

Field of the Invention

The present invention generally relates to techniques for recognizing a target within an image sequence, and more particularly to a method and an
10 equipment for extracting image features from the image sequence which describes a time sequence of frames of the image.

The image sequence refers to an image which is obtained from a video camera, weather radar
15 equipment, remote sensing or the like, for the purposes of monitoring people, traffic and the like, controlling fabrication processes, analyzing or predicting natural phenomena such as the weather.

Background Art

20 Local (for example, several tens to several hundreds of km²) and short-term (for example, 5 minutes to several hours) precipitation phenomena such as heavy rain, heavy snow and thunderstorm have yet to be elucidated completely. However, the effects of the
25 local and short-term precipitation phenomena on daily lives and various industrial activities are large, and it is an important task to predict the precipitation phenomena.

Conventionally, in order to forecast such
30 local precipitation phenomena, an expert such as a meteorologist visually specifies the phenomena from an observed weather radar image and creates a weather forecast. In addition, the weather forecast is created by analyzing a motion of an echo pattern
35 within a weather radar image, and referring to a predicted echo image which is obtained by predicting a future echo pattern. The former prediction is based

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1 on the regularity of the weather phenomena acquired by
the expert from past experiences, and requires years
of skill. On the other hand, according to the latter
prediction using image analysis, it is assumed in most
5 cases that the phenomenon of immediately preceding
several hours is maintained, and it is thus impossible
to follow a rapid change in the phenomenon even though
the forecast most expected to predict such a rapid
change. Furthermore, because it is impossible to
10 satisfactorily represent the phenomena such as an
accurate moving velocity, appearance, disappearance,
deformation and the like of a precipitation region,
there is a problem in that the prediction accuracy is
insufficient.

15 Accordingly, as one method of making an
improvement with respect to the above described
problem, it is conceivable to utilize a repeatability
of the weather phenomena that "similar weather
phenomena occur repeatedly", and to automatically
20 retrieve past weather radar images with similar
phenomenons based on the weather radar image, so as to
present the similar past weather radar images to the
expert. Alternatively, it is conceivable to
categorize the weather radar images into categories of
25 the weather phenomena, and to select and apply a
prediction technique suited for each specified weather
phenomenon. In order to realize such methods, it is
necessary to extract an image feature value
(hereinafter also simply referred to as an image
30 feature) from the weather radar image which is an
image sequence data.

Conventionally, as methods of extracting the
image feature of the image sequence, texture analysis
techniques which obtain the features of a texture
35 within a still image, and motion estimation techniques
which obtain a displacement quantity of the image
pattern between frames of the image sequence have been

1 proposed.

For example, Robert M. Haralick,
"Statistical and Structural Approaches to Texture",
Proceedings of the IEEE, Vol.67, No.5, May 1979
5 proposes a statistical texture analysis which is one
approach of the conventional texture analysis
technique. According to this statistical texture
analysis, statistics such as "a frequency of existence
of a combination of a certain pixel and another pixel
10 located 3 pixels to the right of the certain pixel
having a luminance difference of 1 between the certain
pixel and the other pixel" is calculated, and the
image features are extracted. This statistical
texture analysis is used to detect a difference in
15 two-dimensional image features such as a pattern
(called "texture") on the image surface obtained by a
repetition of basic graphic elements. More
particularly, a set of basic elements called
primitives is first obtained from the image of 1 frame
20 of the image sequence by a process such as image
binarization. Next, a spatial feature such as
directionality is calculated as the statistics such as
the direction and length of an edge of each primitive.
In addition, the spatial feature such as the
25 regularity of the above described repetition of the
primitives is calculated from relative position
vectors among the primitives.

The image feature proposed by Robert M.
Haralick referred above includes a feature value which
30 is defined from a co-occurrence matrix of the image
gray level. The co-occurrence matrix is a matrix
having as its element a probability $P_g(i, j)$, ($i, j =$
 $0, 1, \dots, n-1$) that a point which is separated by a
constant displacement $\delta=(r, \theta)$ from a point having a
35 gray level (or brightness or intensity) i in the image
has a gray level j . For example, feature values such
as those described by the following formulas (0.1) and

1 (0.2) can be calculated from the co-occurrence matrix,
 where δ is set to $r = 1$, $\theta = 0$ (deg), for example.

$$5 \quad \text{angular second moment} = \sum_{i=0}^{n-1} \sum_{j=0}^{n-1} \{P_{\delta}(i, j)\}^2 \quad \text{--- (0.1)}$$

$$10 \quad \text{entropy} = -\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} P_{\delta}(i, j) \cdot \log\{P_{\delta}(i, j)\} \quad \text{--- (0.2)}$$

The angular second moment described by the
 formula (0.1) represents the concentration and
 distribution of the elements of the co-occurrence
 15 matrix, and it is possible to measure the uniformity
 of the texture. Such a feature value is used to
 analyze the geographical features from an air
 photograph and sandstone. However, in general, the
 feature value obtained from the co-occurrence matrix
 20 is in many cases unclear as to what is being
 physically measured.

According to the conventional technique
 using the texture analysis, each frame of the image
 sequence is treated as an independent image. For this
 25 reason, no measurement is made with respect to the
 features related to the motion, although the motion is
 an essential element in determining the features of
 the image sequence.

On the other hand, as conventional motion
 30 estimation methods, Yoshio Asuma et al., "A Method
 for Estimating the Advection Velocity of Radar Echoes
 Using a Simple Weather Radar System", Geophysical
 Bulletin of Hokkaido University, Sapporo, Japan,
 Vol.44, October 1984, pp.23-34 or Yoshio Asuma et al.,
 35 "Short-Term Prediction Experiment (Part 1) of Snow
 Precipitation Using a Simple Weather Radar System",
 Geophysical Bulletin of Hokkaido University, Sapporo,

1 Japan, Vol.44, October 1984, pp.35-51 propose methods
of obtaining 2 frames of the image sequence, matching
each small region within the frames, and measuring the
motion (velocity component) of a target included in
5 the small region, for example. These proposed methods
use the images of 2 different frames of the image
sequence. First, a best matching position where a
certain region (normally, a square region) within the
image of one frame best matches the image of the other
10 frame is searched. Next, the moving velocity of the
object within the target region is estimated from a
displacement between the 2 frames and the frame
interval of the 2 frames. A cross-correlation
coefficient of the image gray level value is used to
15 describe the degree of matching of the 2 image
regions. When the gray level distributions within the
2 image regions are respectively denoted by $I_1(i, j)$
and $I_2(i, j)$, the cross-correlation coefficient can be
calculated from the following formulas (0.3), (0.4)
20 and (0.5), where M and N indicate the sizes of the 2
image regions.

$$\sigma = [\sum_{i=1}^M \sum_{j=1}^N (I_1(i, j) I_2(i, j) - MN \bar{I}_1 \bar{I}_2) /$$

$$25 \quad [(\sum_{i=1}^M \sum_{j=1}^N I_1(i, j)^2 - MN \bar{I}_1^2)(\sum_{i=1}^M \sum_{j=1}^N I_2(i, j)^2 - MN \bar{I}_2^2)]^{\frac{1}{2}}$$

--- (0.3)

$$\bar{I}_1 = [\sum_{i=1}^M \sum_{j=1}^N I_1(i, j)] / (MN)$$

--- (0.4)

$$\bar{I}_2 = [\sum_{i=1}^M \sum_{j=1}^N I_2(i, j)] / (MN)$$

--- (0.5)

35

The cross-correlation coefficient is
calculated while shifting the position of one image

1 region on the image, and a search is made for a
displacement (K, L) which makes the cross-correlation
coefficient a maximum. Based on the displacement (K,
L) which is obtained, moving velocity components can
5 be calculated from the following formulas (0.6) and
(0.7), where V_x and V_y respectively denote a x-
component and a y-component of the velocity component,
and Δ denotes the frame interval. If adjacent frames
are used, $\Delta = 1$. In addition, the obtained velocity
10 uses the units "pixels/frame".

$$V_x = K/\Delta \quad \text{--- (0.6)}$$

$$V_y = L/\Delta \quad \text{--- (0.7)}$$

15

The above described method calculates the
moving velocity using an assumption that the target
within the block where the matching is carried out
does not change shape with time and translates
20 uniformly. However, the calculated moving velocity
does not sufficiently reflect the features of the
target non-rigid body which appears and disappears and
locally includes various motion components. According
to the method of measuring the velocity component from
25 the image sequence, it is only possible to measure the
velocity component such as the translation of the
target. In addition, it is impossible to measure the
spatial features such as the shape and surface texture
of the target within the image sequence, and the
30 arrangement of the image elements.

Furthermore, Japanese Laid-Open Patent
Applications No.10-197543 and No.10-206443 propose
methods of detecting a motion trajectory which has a
surface shape and is drawn by the edge or contour of
35 the target within the image plane in a space
(hereinafter also referred to as a spatiotemporal
space) which is formed when the image sequence is

1 stacked in the time-base direction, and measuring the
motion (velocity component) of the target from the
directions of intersection lines formed by a plurality
of different tangent planes tangent to the motion
5 trajectory.

According to the method of measuring the
motion of the target in the spatiotemporal space, the
Hough transform (also called voting) is first used,
for example, and the spatiotemporal space image is
10 transformed into a parameter space which represents
the velocity component (direction and magnitude of the
velocity) of the target object. Next, a peak of the
distribution within the parameter space is detected,
and the velocity component of the target object is
15 obtained from the peak coordinate values. In this
method of measuring the motion of the target, it is
known that the most dominant
translational velocity component within the target
region can be acquired robustiously with respect to
20 noise and occlusion.

Furthermore, as a conventional method of
detecting a dynamic target within the image sequence
and measuring the motion of the target, a method based
on a gradient of the local gray level value is also
25 known.

According to the conventional texture
analysis technique, each frame of the image sequence
is treated as an independent image, and thus, it is
impossible to measure the features related to the
30 motion which is an essential element of the features
of the image sequence. In addition, since this
conventional texture analysis technique extracts the
features for each frame, it is impossible to
distinguish the dynamic target and the background,
35 thereby being easily affected by concealment, that is,
occlusion and noise. As a result, it is difficult to
stably extract the space features of the dynamic

1 target.

Moreover, according to the above described
conventional method of measuring the velocity
component from the image sequence, it is only possible
5 to measure the velocity component such as the
translation of the target, and it is impossible to
measure the features such as the shape and the surface
texture of the target within the image sequence. In
addition, according to the conventional method of
10 measuring the velocity component, it is assumed that a
single and only conspicuous motion component exists in
the region of the image sequence of interest. For
this reason, if a plurality of objects having
different motions coexist in the same region, it is
15 impossible to accurately estimate the velocity
component included in the image sequence.

On the other hand, in the case of the
conventional method of measuring the motion of the
dynamic target, it is assumed that the continuity of
20 the target motion and the unchangeability of the
target shape are maintained. For this reason, in a
situation where an occluding object exists between an
observer and the moving target and the target becomes
visible and invisible, it is difficult to accurately
25 measure the target motion. In such a situation which
is often referred to as an occlusion state,
information such as the existence of the occlusion,
the degree of occlusion and the position of the
occlusion so as to realize a highly accurate
30 measurement of the motion. However, in the situation
where the occlusion occurs, the moving target which is
to be observed appears, disappears and re-appears,
thereby making it difficult to track the target, and
from the practical point of view, it is impossible to
35 acquire information related to the occlusion.

An image sequence such as a weather radar
image obtained from a weather radar equipment is an

1 example of a target which has an indefinite shape,
includes a non-rigid body which appears and
disappears, and is characterized by the motion within
the image. According to the conventional technique,
5 it is difficult to obtain the features peculiar to
such an image sequence. The reason for this
difficulty is that, essentially, the features peculiar
to the above described image sequence cannot be
obtained from the image features obtained from a
10 single image frame or 2 image frames.

Research related to the motion pattern which
changes with time, that is, the temporal texture, is
introduced in Randal C. Nelson and Ramprasad Polana
(Nelson et al.), "Qualitative Recognition of Motion
15 Using Temporal Texture", CVGIP: Image Understanding,
Vol.56, No.1, July, pp.78-89, 1992, and Martin
Szummer, "Temporal Texture Modeling", M.I.T. Media
Laboratory Perceptual Computing Section Technical
Report No.346, 1995, for example.

20 Nelson et al. define feature values such as
the non-uniformity of the flow direction using
statistics calculated from an optical flow field. For
example, these feature values are extracted in the
following manner. First, a normal flow, which is a
25 component in a direction perpendicular to a gray level
gradient within components of the optical flow, is
obtained for each pixel within the image. Next, a
value obtained by dividing an average value of the
magnitudes of the normal flows by a standard deviation
30 is calculated or, values of positive and negative
curls and divergence of the flow are calculated or,
the direction of the flow is made discrete in 8
directions, and a histogram is thereafter created, and
the statistics of the absolute deviation is calculated
35 from the uniform distribution.

The feature value which is obtained in this
manner has an advantage in that the value does not

1 change with respect to the illumination and color.
However, this feature value cannot sufficiently
represent information related to the shape, and there
is a problem in that the optical flow itself cannot be
5 accurately estimated. The measures taken with respect
to the phenomena such as the appearance and
disappearance of the target are also insufficient.

On the other hand, Martin Szummer and
Rosalind W. Picard, "Temporal Texture Modeling", IEEE
10 International Conference on Image Processing,
September 1996 proposes a method of modeling temporal
texture using a spatiotemporal autoregressive model.

In the spatiotemporal autoregressive model,
the value of each pixel is represented, spatially and
15 time-wise, by a linear combination of the values of a
plurality of surrounding pixels, as described by the
following formula (0.8), where $s(x, y, t)$ denotes a
luminance value of the image sequence, $a(x, y, t)$
denotes a Gaussian white noise, and Δx_i , Δy_i and Δt_i
20 denote neighboring pixels.

$$\begin{aligned} s(x, y, t) = & \sum_{i=1}^p \phi_i \delta(x + \Delta x_i, y + \Delta y_i, t + \Delta t_i) \\ & + a(x, y, t) \end{aligned}$$

25

--- (0.8)

A model parameter ϕ_i is estimated from the
input image sequence using the method of least
30 squares. It may be regarded that the estimated model
parameter ϕ_i represents the temporal and spatial
features of the input pattern. A pattern recognition
or the like is made using this model parameter ϕ_i .

However, since this technique uses the local
35 gray level value of the image, the modeling is easily
affected by the change in illumination and noise added
to the image. In addition, the physical meaning or

1 significance of the obtained model parameter ϕ_i is
unclear. Further, because the modeling is based on
the image gray level, there is a disadvantage in that
the structural features of the image cannot be clearly
5 obtained.

Therefore, the echo pattern included within
the weather radar image is a motion pattern of a non-
rigid body which repeats appearing and disappearing,
and it is difficult to represent the features of such
10 a motion pattern using the conventionally proposed
techniques. Accordingly, there are demands to realize
a method and an equipment for extracting image
features which can represent the features of the
motion pattern of the non-rigid body which repeats
15 appearing and disappearing and is included in the
image. In addition, it is expected that the image
feature of the motion pattern of the non-rigid body is
also effective with respect to retrieval, indexing and
the like of a general video database or the like.

20

SUMMARY OF THE INVENTION

Accordingly, it is a general object of the
present invention to provide a novel and useful method
and equipment for extracting image features from image
25 sequence, in which the problems described above are
eliminated and the above described demands are
satisfied.

Another and more specific object of the
present invention is to provide a method for
30 extracting image features from image sequence, which
can obtain both spatial features and temporal features
which are required as features of the temporal
texture. It is also an object of the present
invention to provide an equipment for extracting image
35 features from image sequence, which uses the method
for extracting image features from the image sequence.
It is also an object of the present invention to

1 provide a recording medium recorded with an image
sequence feature extraction program.

The above described objects of the present
invention can be achieved by each of the following
5 sub-goals or, an arbitrary combination of the sub-
goals.

A first sub-goal of the present invention is
to provide a technique for measuring from a plurality
of frames within an image sequence, image features of
10 images including target shapes and patterns, motion
features, and complex non-rigid bodies which appear
and disappear.

A second sub-goal of the present invention
is to provide a technique for stably extracting
15 spatial features of a dynamic target within an image
sequence.

A third sub-goal of the present invention is
to provide a technique for estimating, from an image
sequence which includes a plurality of objects having
20 different motion, a plurality of velocity components
corresponding to each of the moving objects within the
image sequence.

A fourth sub-goal of the present invention
is to provide a technique for extracting, from an
25 image sequence, information related to complex motion
caused by appearance and disappearance of a target and
a non-rigidity of the target.

A fifth sub-goal of the present invention is
to provide a technique for detecting an occlusion of a
30 dynamic target within an image sequence.

In the present invention, in order to obtain
spatial features such as shape and arrangement of
image elements and temporal features such as motion
and occlusion, a motion trajectory is extracted from
35 within a spatiotemporal space image which is obtained
from a plurality of frames of a moving image. The
spatiotemporal space image is a volume which is

1 obtained by successively stacking each of the frames
of an image sequence in a time-base direction, and a
trajectory drawn by each point of a target within the
spatiotemporal space is referred to as the motion
5 trajectory. By use of the motion trajectory, it is
possible to obtain a velocity of the target from a
direction of the motion trajectory within the
spatiotemporal space. Particularly in a case where a
contour or edge is used as each point of the target,
10 the moving contour draws a motion trajectory which has
a surface shape (hereinafter referred to as a
trajectory surface) within the spatiotemporal space.
In the present invention, a tangent plane which is
tangent to this trajectory surface or, a partial plane
15 which is a portion of the trajectory surface, is
regarded as a basic element of feature representation.

Hence, in order to achieve the first sub-
goal described above, a method according to the
present invention for extracting image features from
20 an image sequence in which frames describing a spatial
image are arranged with respect to time, includes:

a step of inputting the image sequence,
a step of acquiring, a motion trajectory of an
image contour included within a region which is
25 defined by an arbitrary space range and time range
within the input image sequence, as three-dimensional
volume data drawn within a spatiotemporal space in
which each of the frames are stacked in time sequence,
and

30 a step of measuring temporal features and spatial
features of the image from the motion trajectory.

The following advantages can be obtained
according to the present invention by use of the
motion trajectory when measuring the image features.
35 In other words, the features such as the movement,
shape, deformation, position, appearance and
disappearance of a target within the image are fully

1 described as characteristics of the trajectory
surface, and can be comprehended as the three-
dimensional volume data. As a result, it is possible
to simultaneously represent the spatial image features
5 and temporal image features.

In addition, when measuring the temporal
features and the spatial features of the image from
the motion trajectory in the present invention, a
histogram of one of tangent planes which are tangent
10 to the motion trajectory and partial planes which may
be included in the motion trajectory is acquired, and
the temporal features and the spatial features of the
image are measured from the acquired histogram of the
planes.

15 It is advantageous to use the histogram of
the tangent planes or the partial planes, because the
temporal features and the spatial features can be
measured robustiously with respect to the noise and
the occlusion. Particularly, by acquiring a histogram
20 of intersection lines of the tangent planes from the
histogram of the tangent planes, it becomes possible
to locally obtain a most dominant velocity component
even from a target which is a non-rigid body such as a
temporal structure and deforms, appears and
25 disappears.

The advantages of obtaining, from the motion
trajectory, the histogram of the tangent planes of the
motion trajectory when measuring the image features,
are as follows. That is, a distribution of motion
30 components (to be more accurate, normal velocity
components) of a target included in a target
spatiotemporal space can be measured stably and
accurately even from an intermittent motion trajectory
caused by appearance and disappearance of the target,
35 occlusion and noise. The normal velocity component is
a velocity component in a direction perpendicular to a
direction of a tangent line at a point on a contour.

1 In addition, since information related to the shape of
the contour and the arrangement of the image elements
is obtained as the histogram of the tangent planes,
together with the measurement of the motion component,
5 it becomes possible to also measure the spatial
features.

A simplest method of obtaining the normal
velocity component calculates a local gradient of an
image gray level component. In this case, the
10 features of local surfaces obtained from among
adjacent pixels or the like are extremely sensitive to
the deformation of the target. For this reason, it is
difficult to acquire the normal velocity component
with a high accuracy. On the other hand, according to
15 the method of the present invention which obtains the
histogram of the tangent planes of the motion
trajectory, it is possible to obtain a likelihood that
an original motion exists from the degree of the
tangent planes being tangent to the motion trajectory,
20 even in a case where motion trajectory is intermittent
(for example, a case where a point moves while
repeating ON and OFF states). This degree of the
tangent planes being tangent to the motion trajectory
can be obtained from a weighted sum total of gray
25 level values of a number of pixels of the motion
trajectory where the tangent plane passes within the
spatiotemporal difference image.

According to a first embodiment of the
present invention, attention is drawn to graphics or a
30 set of pixels included within a region having an
arbitrary spatial range and a time range within an
image sequence, that is, attention is drawn to a
target or an edge or contour of the target. When each
of the frames within the image sequence are
35 successively stacked in the time-base direction, it is
possible to obtain a motion trajectory drawn within
the spatiotemporal space by the target or the edge or

1 contour of the target. Next, by measuring the image
features of the image sequence from the features of
the motion trajectory such as the shape, position and
direction, the features (spatial features) such as the
5 surface shape of the target within the image sequence
are measured together with information (temporal
features) related to the motion which is an essential
element of the features of the image sequence. By
extracting the contour of the moving target and
10 defining feature values based on the distribution of
the tangent planes which are tangent to the motion
trajectory, it becomes possible to clarify the
significance of the defined features and to obtain
structural features of the image.

15 In addition, in the first embodiment of the
present invention, the histogram of the tangent planes
tangent to the motion trajectory or the histogram of
the partial planes forming the motion trajectory is
obtained as a distribution of votes accumulated in a
20 parameter space (voting space) which is obtained by a
three-dimensional Hough transform, for example. As a
result, it is possible to obtain a histogram related
to the directions of the contour and edge of the
target, and to obtain information related to the shape
25 of the target from this histogram. In addition, by
investigating the direction of the intersection lines
from the plurality of different tangent planes, it is
possible to simultaneously obtain the velocity
components in the image of the target.

30 The three-dimensional Hough transform
calculates the weighted sum total of the gray level
values of the number of pixels of the motion
trajectory where the tangent plane passes within the
spatiotemporal difference image, with respect to
35 parameters θ , ϕ and ρ of each plane. By using the
Hough transform to obtain the distribution of the
tangent planes of the motion trajectory, there is an

1 advantage in that the distribution of the tangent
planes can be obtained robustiously with respect to
the noise and the occlusion. The Hough transform
takes into consideration, with respect to each of the
5 pixels forming the motion trajectory, all of the
planes which may pass the pixels. In addition, an
operation of increasing the value of the element
within the parameter space corresponding to the set of
the planes by the value of the pixel is repeated with
10 respect to all of the pixels. Thus, even if a portion
of the pixels are missing, the undesirable effects
with respect to the accuracy of the tangent planes as
a whole are suppressed, and the distribution of the
tangent planes can be measured stably.

15 In the first embodiment of the present
invention, the image features are extracted from the
motion trajectory spanning a plurality of frames. As
a result, it is possible to extract the features
robustiously with respect to an external disturbance
20 which occurs in a burst manner in only a single frame.
In addition, the dominant velocity components and
other motions (appearance, disappearance and the like)
can be detected separately, and various information
related to the motion can be obtained by obtaining a
25 combination of the motions and the frequency of the
motions.

Furthermore, the first embodiment of the
present invention utilizes the histogram of the
intersection lines in order to obtain the dominant
30 translational velocity components. In a case where
the target translates uniformly within a certain
spatiotemporal space region, 2 mutually non-parallel
tangent planes tangent to the trajectory surface have
a unique intersection lines. This intersection line
35 has a characteristic such that the direction of this
intersection line matches a moving direction of the
target within the spatiotemporal space. Hence, a

1 histogram of the directions of the intersection lines
made up of various combinations of the tangent planes
included within the spatiotemporal space region is
obtained. Velocity components corresponding to the
5 directions of the intersection lines indicating the
most frequent values within the histogram are obtained
as the dominant translational velocity components
within the spatiotemporal space region. For this
reason, in a case where the tangent plane is partially
10 occluded and a portion of the tangent plane disappears
or, even in a case where the noise exists, there is an
advantage in that the translational velocity
components can be obtained in a relatively stable
manner. Random noise has the effect of uniformly
15 increasing the distribution of the tangent planes.
Hence, it is possible to reduce the effect of the
estimated velocity components becoming different from
the original velocity components due to the random
noise.

20 Moreover, according to the present
invention, in order to achieve the second sub-goal
described above, the spatial features such as the
strength of the directionality and the scattering (or
concentration) of the contour of the target which
25 moves at the velocity estimated from the histogram of
the tangent planes as described above are obtained.
Hence, the distribution of the tangent planes
corresponding to the contour moving at the estimated
velocity component, that is, the partial space of the
30 parameter space of the tangent planes, is extracted,
and used for the measurement of the spatial features.
The advantages of using the histogram of the tangent
planes corresponding to the contour which moves at a
certain velocity component in order to measure the
35 spatial image features are that it is possible to
select only a target which moves at a specific
translational velocity component and to extract the

1 spatial features of the selected target.

In the second embodiment of the present invention, the contour and the edge of the target within the image sequence is transformed into a motion trajectory drawn within the spatiotemporal space. For this reason, it is possible to simultaneously comprehend the spatial features such as the shape and the arrangement (or orientation) of the target and the temporal features such as the velocity component. As a result, it is not only possible to obtain the dominant translational velocity of the target, but to also extract the spatial features of the target from the tangent planes corresponding to the contour and the edge of the target.

15 Further, in the second embodiment of the present invention, the contour and the edge within the image are treated as one group in a case where the contour and the edge are arranged discretely and linearly. Consequently, it is possible to extract the image features by taking into account the effects of grouping by the human senses.

The feature values of the strength of the directionality extracted in the second embodiment of the present invention is one of spatial feature values (pattern, texture) of the pattern. The strength of the directionality describes the degree of the strength of the directionality of the contour of the pattern or, the arrangement of the contour. The feature value of the strength of the directionality becomes large in the case of a pattern having many linear contours and contour arrangements. On the other hand, the feature value of the strength of the directionality becomes small in the case of a pattern in which contours in various directions coexist. For example, in the second embodiment of the present invention, the strength of the directionality is defined to be large when only a straight line in one

1 direction exists within the target image region and to
be small in the case of a circle in which components
in all directions uniformly exist within the target
image region.

5 In addition, the feature value of the
concentration of the contour is also one spatial
feature value of the pattern, and describes the degree
of concentration of the contour. The concentration
becomes large for a fine image, and becomes small for
10 an image having clear edges such as the case of a line
drawing.

The third sub-goal of the present invention
can be achieved by acquiring a plurality of relatively
dominant velocity components based on a histogram of
15 the intersection lines of the tangent planes which are
obtained as described above, and measuring the motion
of the plurality of targets.

In a third embodiment of the present
invention, a histogram of the tangent planes which are
20 tangent to the trajectory surface drawn within the
spatiotemporal space by the moving object, for each of
a plurality of objects which move differently within
the image sequence. Next, a histogram of the
directions of the intersection lines formed by
25 mutually different tangent planes is obtained. The
directions of the intersection lines formed by
mutually different and non-parallel tangent planes are
all the same with respect to the motion trajectories
of the moving objects which translate uniformly at
30 equal velocities and to equal directions, and the
intersection lines have characteristics such that the
directions of the intersection lines match the moving
directions of the moving objects within the
spatiotemporal space. Accordingly, assuming a case
35 where a plurality of objects which move differently
and are included in the image sequence translate
uniformly at equal velocities and to equal directions,

1 peaks with respect to the moving objects appear in the
histogram of the directions of the intersection lines
of the tangent planes. Hence, the third embodiment of
the present invention detects the plurality of peaks,
5 and the velocity component is estimated for each of
the detected velocity components. As a result, it is
possible to obtain a plurality of velocity components
corresponding to the moving objects from the image
sequence including the plurality of objects which move
10 differently.

Moreover, in the third embodiment of the
present invention, the distribution of the directions
of the intersection lines of the tangent planes is
obtained with respect to the plurality of objects
15 which move differently and are included in the image
sequence. Then, with respect to each of the velocity
components estimated from the plurality of peaks
within the histogram, a judgement is made to determine
whether or not each velocity component can be
20 represented as a sum of a combination of other
plurality of velocity components. Only the velocity
component which is judged as not being representable
by the sum of the combination of other plurality of
velocity components is output as the final result.
25 Therefore, in the third embodiment of the present
invention, only the independent and basic velocity
components are selected and output with respect to the
plurality of moving objects.

The fourth sub-goal of the present invention
30 can be achieved as follows. According to the present
invention, for example, the distribution of the normal
velocities (normal flows) of the contour can be
obtained from the distribution of the normal
parameters of the tangent planes projected in a
35 certain space. Next, the uniformity of the motion or,
a specific component of the motion, such as a ratio of
a high-velocity component, is calculated from the

1 normal flow distribution. By obtaining the histogram
of the normal flow from the distribution of the
tangent planes, it is possible to stably and
accurately obtain the histogram of the normal flow,
5 even from an image in which the appearance and
disappearance of the target, occlusion and noise
exist.

According to the optical flow which is a
conventional representation of motion of the general
10 image sequence, there is a problem in that the optical
flow is affected by the aperture problem. For
example, in a case where a linear edge with invisible
end points exists within an observation range (within
a cut out spatiotemporal region) and this linear edge
15 uniformly translates, the true velocity of the target
cannot be uniquely determined. For this reason, when
an attempt is made to estimate the true velocity in
the image including such an image structure, the
estimated velocity easily becomes indefinite and
20 unstable. In addition, the application range becomes
limited because the translation of the target is
estimated. Accordingly, in the fourth embodiment of
the present invention, the histogram of the normal
flow, and not the optical flow, is obtained, and it is
25 possible to calculate from this histogram the feature
values related to the motion, because the normal flow
can be uniquely determined even in the case of the
linear edge with invisible end points. As a result,
it is possible to comprehend complex and wide variety
30 of motions without being affected by the aperture
problem. Furthermore, it is possible to stably and
simply obtain from the spreading of the histogram the
feature values of the motion uniformity of the target
within the image sequence.

35 When obtaining the normal flow of a pixel
within the image sequence according to the prior art,
a gray level difference of the pixels which are

1 spatially and time adjacent is calculated. Hence, in
a case where the noise is superimposed on the image,
the feature values of the motion of the target cannot
be accurately and stably obtained because the feature
5 values are excessively affected by the noise. On the
other hand, according to the fourth embodiment of the
present invention, the histogram of the normal flow is
obtained by obtaining the motion trajectory having the
surface shape and drawn in the spatiotemporal space by
10 the moving contour of the target, and then extracting
the histogram of the tangent planes tangent to this
motion trajectory. The fourth embodiment of the
present invention focuses on the point that the
histogram of the normal flow is obtained as the
15 histogram of the tangent planes tangent to the motion
trajectory. In other words, in the fourth embodiment
of the present invention, the moving contour of the
object is represented as the surface within the
spatiotemporal space, and the most appropriate tangent
20 plane to the surface is obtained. Therefore, the
normal flow is calculated based on a wide range of
information as compared to the prior art, and there is
an advantage in that the normal flow can be detected
stably even in a case where noise traverses the image.
25 As a result, even under an environment in which the
noise added to the image and the appearance and
disappearance of the target occur, it is possible to
accurately and stably calculate the motion features
depending on the effects of the noise added to the
30 image and the appearance and disappearance of the
target.

In the fourth embodiment of the present
invention, the motion uniformity is calculated as the
feature value. This motion uniformity describes the
35 diversity of the motion included within the
spatiotemporal space region. Although the motion
uniformity is high with respect to the motion of a

1 rigid body, the motion uniformity is low with respect
to a non-rigid body which easily appears and
disappears and is easily deformed. In addition, even
in the case of the same target, the feature value of
5 the motion uniformity decreases when the amount of
noise added to the image increases. For this reason,
the feature value of the motion uniformity can be used
to judge the rigidity or non-rigidity and to measure
the amount of noise. For example, a specific motion
10 uniformity f_2 in the fourth embodiment of the present
invention takes a maximum value when the linear edge
(contour) within the spatiotemporal space region
translates uniformly. On the other hand, in a case
where the contours of all velocities and directions
15 exist at the same ratio, the motion uniformity f_2 has
a characteristic such that the value of f_2 approaches
0 in the case of random noise, for example.

Furthermore, in the distribution of the
normal flow component, the fourth embodiment of the
20 present invention extracts a ratio occupied by
velocity components greater than or equal to a certain
velocity as the feature value of the velocity. Such
high-velocity components of the velocity occur in many
cases where the target abruptly disappears or appears.
25 Moreover, the high-velocity components also occur in
cases where the gray level value of the target surface
abruptly changes over a wide range. Therefore, the
ratio of the high-velocity components, that is, the
feature value, is effective for use in detecting the
30 abrupt appearance or disappearance of the target, the
change in the surface gray level value and the like.

In addition, according to the present
invention, the temporal features related to the
occlusion, appearance and disappearance of the target
35 are extracted. Thus, the tangent planes tangent to
the motion trajectory are detected from the histogram
of the tangent planes, and the distribution of the

1 motion trajectory on the detected tangent planes is
output as the image. Next, information related to the
occlusion is defined from the intermittence or run
length of the motion trajectory along the moving
5 direction. As a result, the fifth sub-goal of the
present invention is achieved.

Therefore, the following advantages can be
obtained by utilizing the distribution image of the
motion trajectory on the tangent planes in order to
10 obtain the degree of occlusion. That is, one point on
the contour of the uniformly translating target has a
characteristic such that this one point moves on one
tangent plane. Thus, it is possible to measure the
intermittence of the motion trajectory by tracking the
15 distribution of the motion trajectory on the tangent
planes in the moving direction. On the other hand, in
general, when an attempt is made to measure the
intermittence of the motion by tracking each
individual contour point on the image, it is necessary
20 to make a correspondence of the contour points among
the frames. However, in the actual environment which
is full of noise and the like, such a correspondence
of the contour points is difficult to make, and the
degree of occlusion cannot be measured stably and
25 accurately.

In the fifth embodiment of the present
invention, the distribution of the motion trajectory
within the spatiotemporal space is first obtained with
respect to the dynamic target (moving target) included
30 in a plurality of frames within the image sequence.
Next, the motion trajectory is represented as a set of
the tangent planes. When the dynamic target is
occluded, that is, when occlusion occurs, a
discontinuity occurs in the motion trajectory of the
35 target corresponding to the occlusion part.
Accordingly, when the target makes a translation
motion on the image, the motion trajectory of the

1 target is transformed into the set of the same tangent
planes regardless of whether or not the occlusion
exists. Hence, according to the fifth embodiment of
the present invention, the distribution of the motion
5 trajectory on the tangent planes is extracted as the
image, and the motion trajectory in the image is
tracked, so that the information related to the
occlusion can be measured by measuring the run length
of the motion trajectory.

10 In addition, the fifth embodiment of the
present invention is also applicable to cases other
than the general occlusion. For example, the fifth
embodiment of the present invention may be applied to
a target which repeats appearing and disappearing,
15 such as the case of an echo cell which is included in
a weather radar image and repeats appearing and
disappearing while moving generally along the
atmospheric flow. In this case, by regarding the
appearance and disappearance of the target as the
20 occlusion, it is possible to extract the information
such as the life cycle and appearing frequency of each
element which is called the echo cell within the
weather radar image.

An occlusion ratio can be obtained by
25 measuring the lengths of an interval in which the
target is visible (existing) and an interval in which
the target is invisible (not existing), and obtaining
a ratio of the length of the invisible interval with
respect to the entire interval. The occlusion ratio
30 is an effective feature value for evaluating a
situation where an occluding object exists between the
moving object and the camera, for example. When the
moving object moves to the rear side of the occluding
object, this moving object becomes invisible. The
35 moving object becomes visible when this moving object
comes out from the rear side of the occluding object.
In addition, even in a case where the target has a

1 life cycle and repeats disappearing after appearing,
the target becomes visible and invisible, and it may
be regarded that the utilization of the occlusion
ratio is effective. In the case where the weather
5 radar image is the target, the length of the interval
in which the target is visible (existing) corresponds
to the life cycle of the echo cell, and thus, this
length may be used as an index corresponding to the
life cycle of the atmospheric structure called a
10 convection cell.

Therefore, according to the present
invention, it is possible to obtain from the
distribution of the tangent planes of the motion
trajectory both the temporal features including
15 information related to the velocity components
(directions and magnitudes), motion uniformity, ratio
of specific velocity components and occlusion, and
spatial features including information related to the
concentration (scattering) of the contour arrangement
20 and the strength of the directionality of the contour
arrangement.

Other objects and further features of the
present invention will be apparent from the following
detailed description when read in conjunction with the
25 accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a system block diagram showing a
construction of a system for extracting image features
30 from an image sequence according to the present
invention;

FIG. 2 is a system block diagram showing a
functional system structure of a first embodiment of
the present invention;

35 FIG. 3 is a flow chart for explaining an
operation of the system structure of the first
embodiment of the present invention;

1 FIG. 4 is a diagram for explaining a polar
coordinate representation of a plane within a three-
dimensional space in the first embodiment of the
present invention;

5 FIG. 5 is a diagram showing a distribution
of parameters of planes which can pass one point in a
spatiotemporal space region in the first embodiment of
the present invention;

10 FIG. 6 is a system block diagram showing the
functional system structure of a second embodiment of
the present invention;

15 FIG. 7 is a system block diagram showing a
construction of a feature extraction unit of the
second embodiment of the present invention;

20 FIG. 8 is a diagram for explaining that a
direction of intersection lines of tangent planes of a
motion trajectory within the spatiotemporal space in
the second embodiment of the present invention matches
a direction of the motion trajectory;

25 FIG. 9 is a diagram for explaining a method
of representing a straight line within the three-
dimensional space in the second embodiment of the
present invention;

30 FIG. 10 is a diagram showing a range of a
tangent plane distribution corresponding to a target
having uniform translational velocity components
within a parameter space;

35 FIG. 11 is a system block diagram showing a
construction of a feature extraction unit of a third
embodiment of the present invention;

FIG. 12 is a system block diagram showing a
functional system structure of a fourth embodiment of
the present invention;

FIG. 13 is a flow chart for explaining an
operation of the system structure of the fourth
embodiment of the present invention;

FIG. 14 is a system block diagram showing a

1 construction of a normal flow detector of the fourth
embodiment of the present invention;

FIG. 15 is a diagram showing a three-
dimensional representation of a histogram of normal
5 flows;

FIG. 16 is a system block diagram showing a
functional system structure of a fifth embodiment of
the present invention;

FIG. 17 is a flow chart for explaining an
10 operation of the system structure of the fifth
embodiment of the present invention;

FIG. 18 is a system block diagram showing a
dynamic target detector of the fifth embodiment of the
present invention;

15 FIGS. 19A, 19B and 19C respectively are
diagrams showing 3 input image sequence frames used in
an application of the first embodiment of the present
invention;

FIGS. 20A, 20B and 20C respectively are
20 diagrams showing distributions of the motion
trajectories obtained from the image sequence shown in
FIGS. 19A, 19B and 19C by the application of the first
embodiment of the present invention;

FIGS. 21A, 21B and 21C respectively are
25 diagrams showing vote distributions obtained in a
normal parameter space memory from the image sequence
shown in FIGS. 19A, 19B and 19C by the application of
the first embodiment of the present invention;

FIG. 22 is a diagram showing velocity
30 components obtained from the image sequence shown in
FIGS. 19A, 19B and 19C by the application of the first
embodiment of the present invention;

FIG. 23 is a diagram showing an input image
sequence used in an application of the second
35 embodiment of the present invention;

FIG. 24 is a diagram showing a distribution
of tangent planes obtained from the image sequence

1 shown in FIG. 23 by the application of the second
embodiment of the present invention;

FIG. 25 is a diagram showing a directional
histogram of contours obtained by the application of
5 the second embodiment of the present invention;

FIG. 26 is a diagram showing a spatial
arrangement of the contours obtained by the
application of the second embodiment of the present
invention;

10 FIGS. 27A, 27B and 27C respectively are
diagrams for explaining a process applied with the
third embodiment of the present invention;

FIGS. 28A and 28B respectively are diagrams
showing a basic pattern image and a pattern image
15 added with noise of 1 frame of an image sequence used
in an application of the fourth embodiment of the
present invention;

FIGS. 29A and 29B respectively are diagrams
showing a histogram of normal flows with respect to
20 the basic pattern and a histogram of normal flows with
respect to the pattern added with noise which are
obtained by the application of the fourth embodiment
of the present invention;

FIG. 30 is a diagram showing a change in
25 feature values of motion uniformity obtained by the
application of the fourth embodiment of the present
invention in a case where an amount of noise added to
the image is changed; and

FIGS. 31A, 31B, 31C, 31D and 31E
30 respectively are diagrams for explaining an
application of the fifth embodiment of the present
invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

35 FIG. 1 shows the construction of a system
for extracting image features from an image sequence
according to the present invention. The system shown

1 in FIG. 1 includes an image sequence supply source 1
and an image feature extraction equipment 2. The
image feature extraction equipment 2 includes an input
unit 10 which receives an image sequence from the
5 image sequence supply source 1 by a communication, via
a recording medium or the like, for example, and a
frame memory 14 which is coupled to the input unit 10
via a bus 12 and stores image data of the image
sequence or the like from the input unit 10. The
10 image feature extraction equipment 2 also includes a
processor or a processor system 16 which carries out
an image feature extraction process, a program memory
18 such as a ROM which stores an image feature
extraction process program to be executed by the
15 processor system 16, and a RAM 20 which stores data
used by the image feature extraction process. The
image feature extraction equipment 2 further includes
an output unit 22 such as a printer and a display
which displays a processed result or image data, an
20 input unit 24 such as a keyboard and a mouse which
inputs instructions from an operator, and a storage
unit 26. This storage unit 26 stores the processed
result of the image feature extraction process, and
may also store the image feature extraction process
25 program. The processor system 16 may be formed by a
general-purpose CPU. However, the processor system 16
may also be formed by a combination of the general-
purpose CPU and a signal processor which carries out a
high-speed operation, a hardware exclusively for
30 processing images, or the like.

Next, a description will be given of various
embodiments of an image feature extraction method
according to the present invention which may be used
in the above described system which extracts the image
35 features from the image sequence.

FIG. 2 shows the functional system structure
of a first embodiment of the present invention. This

1 embodiment realizes a technique for measuring image
features of images from a plurality of frames within
the image sequence. The image features include the
shape and pattern of the target, motion features, and
5 appearance and disappearance of complex non-rigid
bodies.

The system structure of the first embodiment
of the present invention includes an input unit 30
which inputs image sequence data, a processor 100
10 which extracts image features from the image sequence
data, an after-processor 40 which further processes a
processed result of the processor 100, and an output
unit 50 which outputs processed results of the
processor 100 and the after-processor 40.

15 FIG. 3 shows a flow chart for explaining the
operation of the system structure of the first
embodiment of the present invention. A description of
the first embodiment of the present invention will now
be given with reference to FIGS. 2 and 3.

20 In a step 10 shown in FIG. 3, the image
sequence data is input to the input unit 30. The
processor 100 includes a motion trajectory extraction
unit 102, and in a step 12, the motion trajectory
extraction unit 102 extracts from the image sequence
25 data input to the input unit 30 a target region where
the image features are to be measured, and extracts a
motion trajectory drawn by an edge or a contour within
this target region. The motion trajectory extracted
by the motion trajectory extraction unit 102 is stored
30 in a spatiotemporal space memory 110 of the processor
100.

Next, in a step 14, a Hough transform unit
104 of the processor 100 carries out a three-
dimensional Hough transform with respect to the target
35 region to be measured, and measures the features of
the motion trajectory. A three-dimensional voting
space obtained by the Hough transform carried out by

1 the Hough transform unit 104 is stored in a three-
dimensional voting space memory 112 of the processor
100.

5 In a step 16, a space projection unit 106 of
the processor 100 projects the three-dimensional
voting space stored in the three-dimensional voting
space memory 112 to a two-dimensional space, and
stores a distribution of projected results in a normal
parameter space memory 114 of the processor 100. The
10 distribution of the projected results stored in the
normal parameter space memory 114 may be output as it
is via the output unit 50 in a step 22.

15 In a step 18, a feature extraction unit 108
of the processor 100 extracts temporal features and
spatial features of the image sequence, based on the
distribution of votes stored in the normal parameter
space memory 114 and the three-dimensional voting
space stored in the three-dimensional voting space
memory 112. The extracted temporal features and
20 spatial features may be output as they are via the
output unit 40 in the step 22.

Alternatively, in a step 20, the after-
processor 40 receives values of the temporal features
and spatial features extracted in the feature
25 extraction unit 108 as feature values, and carries out
an after-process such as a classification of the image
sequence which is first input based on the feature
values. In the step 22, results of the after-process
carried out by the after-processor 40 are output via
30 the output unit 50.

The output unit 50 makes an output to a
display unit or a file unit in response to the vote
distribution stored in the normal parameter space
memory 114, the feature values generated by the
35 feature extraction unit 108, and the classification
results of the image sequence generated by the after-
processor 40.

1 Next, a more particular description will be
given of the operation of each of the constituent
elements of the processor 100.

 After extracting from the image sequence the
5 target region where the image features are to be
measured, the motion trajectory extraction unit 102
constructs the motion trajectory which is drawn by the
edge of contour of the target within the image in the
spatiotemporal space in the form of three-dimensional
10 volume data.

 As an example of the three-dimensional
volume data describing the motion trajectory, it is
possible to calculate a difference between the frames
of the image sequence, for example, and to utilize a
15 spatiotemporal difference image $D(x, y, t)$ using a
positive value, a negative value or an absolute value
of this difference. This spatiotemporal difference
image $D(x, y, t)$ is stored in the spatiotemporal space
memory 110 as the motion trajectory. When using the
20 positive value of the difference, the spatiotemporal
difference image $D(x, y, t)$ can be calculated from the
following formula (1), where I denotes the image
sequence.

$$25 \quad \begin{cases} D(x, y, t) = I(x, y, t+1) - I(x, y, t) \\ \quad \quad \quad \text{if } I(x, y, t+1) - I(x, y, t) > 0 \text{ and} \\ D(x, y, t) = 0 \text{ otherwise} \end{cases} \quad \text{--- (1)}$$

30 Accordingly, a cylindrical motion trajectory
is generated, and the edge and the contour within the
image can be represented as a base curve of a
cylinder. The magnitude of the gray level value of
the spatiotemporal difference image $D(x, y, t)$ is
35 approximately proportional to the motion quantity and
the magnitude of the discontinuity seen in the spatial
distribution of the luminance of the edge and the

1 contour within the image. Of course, any method
capable of extracting the motion trajectory as the
three-dimensional volume data may be used in place of
the above described method using the spatiotemporal
5 difference image.

Next, in order to acquire the features
related to the motion trajectory, the Hough transform
unit 104 inputs the three-dimensional volume data
representing the motion trajectory extracted by the
10 motion trajectory extraction unit 102, that is, the
spatiotemporal difference image $D(x, y, t)$ in this
particular case, and generates the vote distribution
by voting within the parameter space (also referred to
as the voting space).

15 In this embodiment in particular, the
distribution of the tangent planes which may be
tangent to the motion trajectory within the
spatiotemporal space (or the distribution of partial
planes of the motion trajectory) is detected by the
20 three-dimensional Hough transform, and the histogram
of the tangent planes is stored in the three-
dimensional voting space memory 112 in the three-
dimensional array.

FIG. 4 shows a polar coordinate
25 representation of a plane within a three-dimensional
space. As shown in FIG. 4, a plane which passes a
point (x_i, y_i, t_i) in the three-dimensional space can
be described by the following formulas (2) through (5)
using polar coordinates (θ, ϕ, ρ) , where (θ, ϕ)
30 indicates the normal direction of the plane and ρ
indicates a minimum distance from the origin to the
plane.

$$x_i \cdot \cos\theta \cdot \sin\phi + y_i \cdot \sin\theta \cdot \sin\phi + t_i \cdot \cos\phi = \rho$$

35 --- (2)

$$0 \leq \theta < 2\pi$$

--- (3)

1

$$0 \leq \vartheta < \pi/2 \quad \text{--- (4)}$$

$$-\infty < \rho < \infty \quad \text{--- (5)}$$

5

A space in which a plane described by 3 parameters exists will be referred to as a plane parameter space S_p . From the formula (2), it may be seen that 1 point (x_i, y_i, t_i) within the three-
10 dimensional space corresponds to 1 surface within the plane parameter space S_p .

FIG. 5 shows a distribution of parameters of planes which can pass 1 point in a spatiotemporal space region. Actually, the plane parameter space S_p
15 is made discrete by intervals $(\Delta\theta, \Delta\vartheta, \Delta\rho)$, and is stored in a three-dimensional array having discrete micro spaces as elements. In this embodiment, the three-dimensional array is provided in the three-dimensional voting space memory 112. The elements of
20 the three-dimensional array are called cells.

Next, by use of a voting process, the distribution of the tangent planes of the motion trajectory within the target region represented as the spatiotemporal difference image D is acquired as
25 values of the cells within the plane parameter space S_p . The voting process calculates surfaces described by the formula (2) with respect to all pixels of the spatiotemporal difference image $D(x, y, t)$, and increases the values of the cells within the plane
30 parameter space S_p where the surfaces pass by the value of the pixel $D(i, j, t)$ of the spatiotemporal difference image $D(x, y, t)$. After the voting process is carried out with respect to all of the pixels, a total value of the voting accumulated at each cell of
35 the plane parameter space S_p is regarded as the strength of the tangent planes of the motion trajectory having the parameters

1 $(\theta, \varnothing, \rho)$. Accordingly, the voting result represents
the histogram of the target tangent planes. Hence, in
a case where the distribution of the votes in the
plane parameter space S_p forms a peak, coordinates $(\theta,$
5 $\varnothing, \rho)$ where the peak occurs correspond to the
parameters representing the tangent planes of the
motion trajectory included in the spatiotemporal
space.

The space projection unit 106 searches in a ρ
10 direction for a maximum value of the votes
accumulated at the cells, with respect to each (θ, \varnothing)
of the plane parameter space $S_p(\theta, \varnothing, \rho)$ formed in the
three-dimensional voting space memory 112 by the
process carried out by the Hough transform unit 104.
15 The maximum values found by the search are stored in
the two-dimensional normal parameter space memory 114
in a two-dimensional array. A space formed by (θ, \varnothing)
is referred to as a normal parameter space S_N . This
normal parameter space S_N can be described by the
20 following formula (6).

$$S_N(\theta, \varnothing) = \max_{\rho} S_p(\theta, \varnothing, \rho) \quad \text{--- (6)}$$

A space projection process has a function of
25 integrating the distribution of the tangent planes of
the motion trajectory drawn in the spatiotemporal
space by the contour and edge within the target region
to a distribution viewed for each of the same normal
directions independently of the time and position.
30 That is, the integrated distribution represents a
distribution of the tangent planes of the motion
trajectory which is constant with respect to the time
and position. Accordingly, by carrying out the space
projection process, this first embodiment of the
35 present invention can obtain feature values which will
not change with respect to the time and position.

The distribution of the votes within the

1 normal parameter space S_N obtained in the above
described manner reflects the image features of the
input image sequence. For example, in a case where
the target translates at a constant velocity in a
5 constant direction within the measuring region, a
sharp peak appears in the normal parameter space S_N .
It may be seen that the edge and contour of the moving
target form a linear shape when an isolated peak
appears, and that the edge and contour of the moving
10 target form a curved shape when peaks appear in a
curved shape. Furthermore, the vote at the peak
represents the frequency with which the corresponding
edge and contour in the ρ direction appear. The vote
distribution obtained in the normal parameter space S_N
15 represents the temporal features and the spatial
features of the image sequence.

The peaks within the normal parameter space
 S_N spread when the target motion within the region is
inconsistent. Moreover, when the target appears and
20 disappears at random within the measuring region, the
votes in the normal parameter space S_N assume states
as if added with a bias, and it is possible to obtain
an approximately uniform vote distribution.

Or, in a case where various motions of the
25 target overlap, there is an advantage in that the
effects of the various motions appear additively in
the votes in the normal parameter space S_N .

The feature extraction unit 108 extracts the
image features by extracting the temporal features and
30 the spatial features of the image sequence. For
example, in the case described above, the image
features are qualitatively represented by the vote
distribution obtained in the normal parameter space
memory 114, but the features can be extracted by
35 evaluating the isolation of the peak, the connectivity
of the peaks, the vote at the peak and the like.

As described above, according to this first

1 embodiment of the present invention, the motion
trajectory drawn within the spatiotemporal space by
the target or by the edge and contour of the target
within the image when measuring the image features
5 such as the surface shape and motion of the target
included within the image sequence is obtained. In
addition, the histogram of the tangent planes tangent
to the drawn motion trajectory or, the histogram of
the partial planes included in the motion trajectory,
10 is acquired by the Hough transform. Next, the
features within the image sequence are measured from
the histogram. Therefore, it is possible to extract
from the plurality of frames within the image sequence
the spatial features such as the shape and pattern of
15 the target and the temporal features such as the
motion of the target. Furthermore, it is also
possible to measure the image features of a complex
non-rigid body which appears and disappears.

FIG. 6 shows the functional system structure
20 of a second embodiment of the present invention. In
this embodiment, the temporal features and the spatial
features are extracted in the feature extraction unit
108.

The difference between the system structure
25 of the second embodiment of the present invention
shown in FIG. 6 and the system structure of the first
embodiment of the present invention shown in FIG. 2 is
that the output of the three-dimensional voting space
memory 112 is connected to the feature extraction unit
30 108 in the system structure of the second embodiment.
Otherwise, the system structure of the second
embodiment is the same as the system structure of the
first embodiment. Accordingly, a description will
only be given of the feature extraction unit 108 in
35 the following description. A description of the
construction and operation of other constituent
elements of the system structure, namely, the input

1 unit 30, the motion trajectory extraction unit 102,
the Hough transform unit 104, the space projection
unit 106, the spatiotemporal space memory 110, the
three-dimensional voting space memory 112, the normal
5 parameter space memory 114, the after-processor 40 and
the output unit 50, will be omitted since the
construction and operation of these other constituent
elements are the same as those of the first embodiment
of the present invention described above.

10 FIG. 7 shows the construction of the feature
extraction unit 108 of the second embodiment of the
present invention. The feature extraction unit 108
extracts the image features of the image sequence from
the three-dimensional vote distribution obtained by
15 the Hough transform unit 202 and the normal parameter
space vote distribution obtained by the space
projection unit 106, by extracting the features of the
vote distributions. In the case of this embodiment,
the most dominant translational velocity components
20 are extracted as the temporal features, and the
spatial features of the contour and edge of the target
within the image are extracted as the spatial
features. Of course, various other kinds of feature
values may be extracted as the features.

25 The vote distribution stored in the two-
dimensional normal parameter space memory 114 by the
space projection unit 106 is a histogram of the
tangent planes of the motion trajectory drawn within
the spatiotemporal space by the contour and edge
30 within the target region to be measured, when viewed
for each of the normal directions of the tangent
planes. In a case where the target translates in the
same direction at a constant velocity, the
intersection lines of the tangent planes have a
35 characteristic such that the directions of the
intersection lines of the tangent planes all match the
directions of the target motion, as shown in FIG. 8.

1 Hence, in this second embodiment of the present
invention, this characteristic of the intersection
lines of the tangent planes is utilized, and an
intersection line histogram obtaining unit 150 of the
5 feature extraction unit 108 shown in FIG. 7 obtains a
histogram of the intersection lines formed by the
tangent planes, and stores this histogram in an
intersection histogram memory 511. Next, a
translational velocity estimation unit 152 obtains a
10 most dominant translational velocity component within
the target region from the direction of the
intersection line having the highest frequency within
the histogram stored in the intersection line
histogram memory 151.

15 FIG. 9 is a diagram for explaining a method
of representing a straight line. In this embodiment,
the direction of the intersection line can be
represented by the following formulas (7) through (9)
using an angle α which is formed by an intersection
20 line passing the origin and an x-axis when this
intersection line is projected on a x-y plane, and an
angle β which is formed by this intersection line and
the x-y plane (image plane), where $0 \leq \alpha < 2\pi$ and $0 <$
 $\beta < \pi/2$.

25

$$l_x = x_2 - x_1 = \cos\alpha \cdot \cos\beta \quad \text{--- (7)}$$

$$l_y = y_2 - y_1 = \sin\alpha \cdot \cos\beta \quad \text{--- (8)}$$

30

$$l_t = t_2 - t_1 = \sin\beta \quad \text{--- (9)}$$

A space which represents the histogram of
the intersection lines is defined as a space formed by
the 2 parameters α and β , and this space is referred
35 to as an intersection parameter space S_L . In
addition, 2 different points on the intersection line
are denoted by $P_1(x_1, y_1, t_1)$ and $P_2(x_2, y_2, t_2)$.

1 By simultaneously solving the formula (2)
with respect to the 2 points P_1 and P_2 and
substituting the formulas (7) through (9), it is
possible to obtain a relationship of the normal
5 parameter space S_N and the intersection parameter
space S_L as described by the following formula (10).

$$\beta = -\tan^{-1}\{\tan\theta \cdot \cos(\alpha - \theta)\} \quad \text{--- (10)}$$

10 2 tangent planes are described as 2 points
in the normal parameter space S_N , and a curve
described by the formula (10) is obtained when these 2
points are transformed into the intersection parameter
space S_L . The direction of the intersection line of
15 the tangent planes is obtained as an intersection
point of the curve described by the formula (10).

In the second embodiment of the present
invention, with respect to all elements or cells (θ, ϕ)
within the normal parameter space S_N , the value of
20 the normal parameter space $S_N(\theta, \phi)$ is voted for the
cell within the intersection parameter space S_L where
the curve described by the formula (10) passes. By
making such a voting, that is, by carrying out another
Hough transform, the velocity components of the target
25 which may be included in the target region
representing certain velocity components of the target
object are reflected to the vote distribution within
the intersection parameter space S_L .

Next, the translational velocity estimation
30 unit 152 detects the peak of the vote distribution
within the intersection parameter space S_L , and
obtains the most dominant translational velocity
component of the target object within the target
region from the coordinate values (α_p, β_p) of this
35 peak. The direction of the motion is obtained as

$$\alpha_p \quad \text{--- (11)}$$

1 and a magnitude V of the velocity is obtained by the
following formula (12).

$$V = 1/\tan\beta_p \quad \text{--- (12)}$$

5

A vote $S_L(\alpha_p, \beta_p)$ indicating the peak is information
representing the likelihood of a translational
velocity component having a velocity V and a direction
 α_p existing within the target region. The
10 translational velocity component is a feature value
representing the temporal feature, more particularly,
motion feature.

Then, a constraint surface extraction unit
154 of the feature extraction unit 108 shown in FIG. 7
15 operates so as to extract the spatial features. The
constraint surface extraction unit 154 extracts the
distribution of the tangent planes tangent to the
motion trajectory drawn by the contour and edge having
the translational velocity component obtained in the
20 translational velocity estimation unit 152 from the
distribution of the tangent planes stored in the
three-dimensional voting space memory 112.

When the translational velocity component
within the target region is denoted by (α_p, β_p) , a
25 relationship described by the following formula (13)
which is uniquely determined depending on the velocity
component stands between the parameters θ and ϕ in the
normal directions of the tangent planes, based on the
formula (9) described above.

30

$$\phi = -\tan^{-1}\{\tan\beta_p/\cos(\alpha_p-\theta)\} \quad \text{--- (13)}$$

From the relationship described by the
formula (13), the tangent plane distribution
35 corresponding to the contour and edge of the target
having the translational velocity component (α_p, β_p)
becomes restricted on the constraint surface within

1 the θ - ϕ - ρ space. FIG. 10 shows a range of the tangent
plane distribution corresponding to the target having
uniform translational velocity components within the
parameter space, that is, the constraint surface
5 within the parameter space.

The constraint surface extraction unit 154
obtains a tangent plane distribution CS on the
constraint surface from the following formula (14),
based on the characteristic that the tangent plane
10 distribution corresponding to the target having the
uniform translational velocity components becomes
restricted on the constraint surface, where θ
corresponds to a tangent line direction of the contour
and edge, and ρ corresponds to a length of a
15 perpendicular from the origin within the target region
to the tangent line. In addition, the tangent line
direction θ is the direction of a perpendicular from
the origin within the target region to a tangent line
on the contour.

20

$$CS(\theta, \rho) = \{S_p(\theta, \phi, \rho) | \tan\phi \cdot \cos(\alpha - \theta) + \tan\beta = 0\}$$

--- (14)

In the case described above, the constraint
25 surface extraction unit 154 extracts the spatial
features by use of the translational velocity
components obtained by the translational velocity
estimation unit 152. However, the constraint surface
extraction unit 154 may acquire the tangent plane
30 distribution CS on the constraint surface using
arbitrary velocity components obtained from other than
the translational velocity estimation unit 152.

Next, a spatial feature extraction unit 156
of the feature extraction unit 108 shown in FIG. 7
35 extracts the spatial features of the contour and edge
of the target within the image, based on the tangent
plane distribution on the constraint surface obtained

by the constraint surface extraction unit 154.

1 Features related to the directionality of
the contour and edge are extracted as first spatial
features. The first spatial features are extracted
from the distribution of the tangent planes along the
5 parameters in the tangent line direction of the
contour and edge. Features related to the spatial
arrangement of the contour and edge are extracted as
second spatial features. The second spatial features
are extracted from a histogram of the tangent planes
10 in directions perpendicular to the tangent line
direction. More particularly, in this embodiment, the
first spatial features are features related to the
uniformity of the contour direction, that is, the
strength of the directionality. On the other hand,
15 the second spatial features are features related to
the repetition of the contour, that is, concentration
or density of the contour. Next, a description will
be given of the extraction of the features related to
the uniformity of the contour direction and the
20 features related to the repetition of the contour.

First, in order to obtain the uniformity of
the contour direction, a distribution CC representing
a histogram of the tangent line directions of the
contour is obtained by the following formula (15) from
25 the tangent plane distribution CS on the constraint
surface.

$$CC(\theta) = \max_{\rho} CS(\theta, \rho) \quad \text{--- (15)}$$

30 This distribution CC is called a tangent
line direction histogram or a directionality
histogram. In a case where the contour is linear, the
tangent line direction histogram $CC(\theta)$
has a sharp peak at θ corresponding to the direction
35 of the straight line. On the other hand, the peak of
the tangent line direction histogram $CC(\theta)$ becomes

- 1 gradual as the contour approaches a smooth circular
 shape. Hence, in this second embodiment of the
 present invention, a uniformity f_1 of the contour
 direction is defined by the following formula (16).
 5 The uniformity f_1 approaches 1 when the contour is
 linear and has a uniform direction.

$$f_1 = (\max_{\theta} CC(\theta) - \overline{CC}) / \max_{\theta} CC(\theta) \quad \text{--- (16)}$$

- 10 In addition, in order to obtain the features
 related to the repetition of the contour, this second
 embodiment of the present invention considers a
 distribution in the ρ direction of the tangent plane
 distribution CS on the constraint surface. The
 15 tangent plane distribution $CS(\theta, \rho)$ with respect to a
 certain tangent line direction θ corresponds to the
 distribution of the tangent planes on the contour
 located at a distance ρ from the origin within the
 target region. For this reason, in the case of a
 20 contour pattern having the repetition, the tangent
 plane distribution $CS(\theta, \rho)$ in the ρ direction also
 has the repetition. Accordingly, a repetition f_2 of
 the contour having the tangent line direction θ is
 defined by the following formula (17).

$$f_2 = 1 - (\max_{\rho} CS(\theta, \rho) - \overline{CS(\theta, \rho)}) / \max_{\rho} CS(\theta, \rho) \quad \text{--- (17)}$$

- Moreover, a repetition f_3 of the entire contour can be
 30 calculated from the following formula (18).

$$f_3 = 1 - \max_{\theta} \{ (\max_{\rho} CS(\theta, \rho) - \overline{CS(\theta, \rho)}) \} / \max_{\rho} CS(\theta, \rho) \quad \text{--- (18)}$$

- 35 Therefore, according to the second
 embodiment of the present invention, the motion
 trajectory drawn within the spatiotemporal space by

1 the contour and edge of the target which moves in the
image is extracted when measuring the spatial features
such as the shape and arrangement of the target which
has motion and is included within the image sequence.
5 Next, a histogram of the tangent planes tangent to
this motion trajectory is obtained, and the dominant
translational velocity component within the target
region is estimated from the histogram. Then, the
spatial features of the target are measured from the
10 tangent plane distribution corresponding to the
contour and edge of the target having the estimated
velocity component. Thus, the spatial features of a
conspicuous target included in a plurality of frames
can be robustiously extracted with respect to the
15 noise and partial occlusion of the target.

Next, a description will be given of a third
embodiment of the present invention which measures the
motion of a plurality of targets by acquiring a
plurality of relatively dominant velocity components
20 based on a histogram of intersection lines of the
tangent planes which are obtained as described above.

A functional system structure of this third
embodiment of the present invention is the same as
that of the first embodiment of the present invention
25 shown in FIG. 2. The feature extraction unit 108 is
the only structural difference between this third
embodiment of the present invention and the first
embodiment of the present invention. Thus, in the
following, a description will only be given of the
30 feature extraction unit 108 of this third embodiment
of the present invention by referring to FIG. 11. A
description of the construction and operation of other
constituent elements of the system structure, namely,
the input unit 30, the motion trajectory extraction
35 unit 102, the Hough transform unit 104, the space
projection unit 106, the spatiotemporal space memory
110, the three-dimensional voting space memory 112,

1 the normal parameter space memory 114, the after-
processor 40 and the output unit 50, will be omitted
since the construction and operation of these other
constituent elements are the same as those of the
5 first embodiment of the present invention described
above.

The feature extraction unit 108 of the third
embodiment of the present invention includes an
intersection histogram obtaining unit 150 and an
10 intersection histogram memory 151, as shown in FIG.
11. The intersection histogram obtaining unit 150
obtains a histogram of the intersections formed by the
tangent planes, from the normal parameter space vote
distribution which is stored in the normal parameter
15 space memory 114 by the space projection unit 106.
The intersection histogram memory 151 stores the
intersection histogram obtained by the intersection
histogram obtaining unit 150. The intersection
histogram obtaining unit 150 and the intersection
20 histogram memory 151 may have the same construction
and functions as the intersection histogram obtaining
unit 150 and the intersection histogram memory 151 of
the second embodiment of the present invention shown
in FIG. 7. Hence, in the following, a description
25 will be given of the case where the intersection
histogram obtaining unit 150 and the intersection
histogram memory 151 of the second embodiment of the
present invention are applied to this third embodiment
of the present invention. For this reason, a
30 description will not be repeated of the intersection
histogram obtaining unit 150 and the intersection
histogram memory 151 of this third embodiment of the
present invention.

In addition, the feature extraction unit 108
35 shown in FIG. 11 further includes a peak detector 160
and a velocity component calculator 162. The peak
detector 160 detects a plurality of peaks from the

1 intersection histogram stored in the intersection
histogram memory 151. The velocity component
calculator 162 which is connected to the peak detector
160 estimates the velocity component of the target
5 from the plurality of peaks detected by the peak
detector 160.

Next, a detailed description will be given
of the process of the peak detector 160 for detecting
the peaks from the intersection histogram of the
10 intersections formed by the tangent planes of the
trajectory surface stored in the intersection
histogram memory 151.

In the third embodiment of the present
invention, the peak detector 160 judges whether or not
15 the following formula (19) stands with respect to all
combinations of α and β of an intersection histogram
 $S_L(\alpha, \beta)$ within the intersection parameter space,
where $S = \{(\alpha, \beta) | (\alpha_i - \alpha)^2 + (\beta_i - \beta)^2 < r^2, \alpha \neq \alpha_i, \beta \neq \beta_i\}$.

20

$$\forall (\alpha, \beta) \in S, S_L(\alpha_i, \beta_i) > S_L(\alpha, \beta)$$

--- (19)

A combination of (α_i, β_i) such that the
25 formula (19) stands is detected as the vertex of the
peak. In the formula (19), it is judged that a vertex
candidate point (α_i, β_i) is the vertex of the peak
when a value $S_L(\alpha_i, \beta_i)$ of the vertex candidate is
greater than all values $S_L(\alpha, \beta)$ falling within a
30 radius r about the vertex candidate point (α_i, β_i)
which is taken as the center. A plurality of peak
positions $(\alpha_1, \beta_1), (\alpha_2, \beta_2), \dots, (\alpha_N, \beta_N)$ obtained
in this manner are output from the peak detector 160.

If course, methods other than the above
35 described method may be used as long as a plurality of
peaks are obtainable.

The velocity component calculator 162 of the

1 third embodiment of the present invention receives as
the input the positions of the peaks in the histogram
of the intersection line direction detected by the
peak detector 160, and calculates the plurality of
5 velocity components within the image sequence. In
addition, the velocity component calculator 162 judges
the independence with respect to each of the
calculated velocity components. Judging the
independence corresponds, for example, to judging
10 whether or not the velocity component is represented
by a sum of other velocity components. Next, the
velocity component calculator 162 excludes the
velocity components having no independence, that is, a
composite (or combined) velocity component of a
15 plurality of moving objects, and selects and outputs
only the velocity components corresponding to the
moving objects.

In the third embodiment of the present
invention, by applying the formulas (7) through (9)
20 with respect to the position (α_i , β_i) of the peak
point, an x-component and a y-component of the
velocity can respectively be obtained from the
following formulas (20) and (21), where a velocity
component with respect to an i th peak is denoted by v_i
25 $= (v_x, v_y)$.

$$v_x = \cos \alpha_i / \tan \beta_i \quad \text{--- (20)}$$

$$v_y = \sin \alpha_i / \tan \beta_i \quad \text{--- (21)}$$

30

A peak corresponding to a composite velocity
component of the velocity components of the plurality
of moving objects may occur in the histogram S_L of the
intersection line direction. It is desirable that
35 such a composite velocity component is eliminated, and
that only basic velocity components are output with
respect to the moving objects. Hence, in the third

1 embodiment of the present invention, with respect to
each of velocity components v_1, v_2, \dots, v_N obtained
with respect to N peaks, a sum of velocity components
made up of all combinations of other velocity
5 components is calculated, and a check is made to
determine whether or not this sum matches each
velocity component v_i so as to judge the independence.
After the check is made to judge the independence with
respect to all velocity components v_i , only the
10 velocity components which cannot be represented as a
sum of other velocity components, that is, only the
independent velocity components, are selected and
output as the basic velocity components of the
plurality of moving objects.

15 Of course, the method of obtaining the basic
velocity components of the plurality of moving objects
is not limited to the above described method used in
the third embodiment of the present invention.

Therefore, according to the third embodiment
20 of the present invention, the distribution of the
tangent planes on the trajectory surface drawn in the
spatiotemporal space by the contour of the moving
object is obtained, and next, the histogram of the
intersection line direction formed by the mutually
25 non-parallel tangent planes is obtained. Then, the
velocity components are estimated from the positions
of the plurality of peaks in the histogram of the
intersection line direction. As a result, it is
possible to obtain a plurality of velocity components
30 corresponding to each of the plurality of different
moving objects from the image sequence in which the
plurality of different moving objects exist. In
addition, by judging the independence with respect to
the velocity components which are obtained from the
35 plurality of peaks, it becomes possible to extract
only the basic velocity components of each of the
objects.

1 Next, a description will be given of a
fourth embodiment of the present invention.

FIG. 12 shows a functional system structure
of the fourth embodiment of the present invention.

5 This fourth embodiment realizes a technique for
extracting a distribution of normal velocities (normal
flows) of the contour of the image from a plurality of
frames within the image sequence, and measuring motion
uniformity or specific components of motion from the
10 extracted normal flows. The system structure of the
fourth embodiment of the present invention includes a
input unit for inputting the image sequence data, a
processor 100 for extracting image features from the
image sequence data, and an output unit 50 for
15 outputting the processed result of the processor 100.

In this fourth embodiment of the present
invention, the processor 100 includes a target region
extraction unit 120 for extracting a target region
where the features are to be extracted from the image
20 sequence data input to the input unit 30, and a
spatiotemporal space memory 122 for storing the target
region extracted by the target region extraction unit
120. The processor 100 also includes a normal flow
detector 124 for obtaining a histogram of the normal
25 flows, a two-dimensional normal flow memory 126 for
storing the obtained histogram of 2 variables of the
normal flows, and a one-dimensional normal flow memory
128 for storing a histogram of normal flows related to
the magnitude of the velocity. Furthermore, a feature
30 extraction unit 130 of the processor 100 extracts the
feature values related to the motion of the image
based on the histograms of the normal flows stored in
the two-dimensional normal flow memory 126 and the
one-dimensional normal flow memory 128.

35 For example, the output unit 50 outputs the
feature values output from the feature extraction unit
130 to a display unit or a file unit.

1 FIG. 13 shows a flow chart for explaining
the operation of the system structure of the fourth
embodiment of the present invention. The system
structure of this embodiment operates as follows. In
5 a step 40, the image sequence data is input from the
input unit 30 to the target region extraction unit 120
of the processor 100. In a step 42, the target region
extraction unit 120 extracts from the input image
sequence the target region from which the features are
10 to be extracted, and the motion trajectory drawn by
the edge and contour within the target region is
obtained and stored in the spatiotemporal memory 122.
Next, in a step 42, the normal flow detector 124
obtains a histogram of the normal flows within the
15 target region, and stores the histogram in the two-
dimensional normal flow memory 126 and the one-
dimensional normal flow memory 128. In a step 46, the
feature extraction unit 130 extracts the feature
values related to the motion included in the image
20 sequence based on the obtained histogram of the normal
flows. Finally, in a step 48, the output unit 50
outputs the feature values obtained by the feature
extraction unit 130.

Next, a more specific description will be
25 given of the operation of each of the constituent
elements of the processor 100.

The target region extraction unit 120
extracts from the image sequence input from the input
unit 30 a region which has an arbitrary space range
30 and time range and from which the image features are
to be measured. The target region extraction unit 120
stores the extracted region in the spatiotemporal
memory 122.

In the spatiotemporal memory 122, the region
35 extracted from the image sequence by the target region
extraction unit 120 is stored in 2 axes of the image
space and 1 time axis (or time base), that is, in a

1 total of 2 axes, as an array of three-dimensional
image gray level (or brightness or intensity).

The normal flow detector 124 detects the
normal flows of the target object included in the
5 region which is extracted from the image sequence by
the target region extraction unit 120 and stored in
the spatiotemporal memory 122, and calculates a
histogram of the normal flows. The normal flow
detector 124 stores the calculated histogram of the
10 normal flows in the two-dimensional normal flow memory
126 and the one-dimensional normal flow memory 128.

The fourth embodiment of the present
invention employs a method which uses the histogram of
the tangent planes as an example of a method of
15 obtaining the histogram of the normal flows. More
particularly, the method of obtaining the histogram of
the normal flows is realized by the following four
steps S1 through S4.

Step S1: First, a motion trajectory having
20 the surface shape drawn in the three-dimensional
spatiotemporal space by the moving contour of the
target within the image when each of the frames of the
image sequence are stacked in the time-axis direction
is obtained.

25 Step S2: Next, a distribution of the
tangent planes tangent to the motion trajectory having
the surface shape is obtained.

Step S3: A histogram of 2 variables of the
normal flows is obtained from the histogram of the
30 tangent planes.

Step S4: A histogram of 1 variable of the
normal flows is obtained from the histogram of the
tangent planes.

In the fourth embodiment of the present
35 invention, the above described step S1 can be realized
by the same construction and functions as the
combination of the motion trajectory extraction unit

1 102 and the spatiotemporal space memory 110 of the
first embodiment of the present invention described
above.

5 In addition, the above described step S2 can
be realized by the same construction and functions as
the combination of the Hough transform unit 104 and
the three-dimensional voting memory 112 of the first
embodiment of the present invention described above.

10 Further, with regard to the above described
step S3 of the fourth embodiment of the present
invention, it is possible to store the two-dimensional
normal flows representing the histogram of 2 variables
of the normal flows into the two-dimensional normal
flow memory 126 by employing the same construction and
15 functions as the combination of the space projection
unit 106 and the normal parameter space memory 114 of
the first embodiment of the present invention
described above.

20 However, with regard to the above described
step S4, it is necessary to separately calculate the
histogram of a variable of the normal flows.

FIG. 14 is diagram for explaining in more
detail the normal flow detector 124 which realizes the
above described steps S1 through S4. As shown in FIG.
25 14, the normal flow detector 124 includes the motion
trajectory extraction unit 102, the spatiotemporal
memory 110, the Hough transform unit 105, the three-
dimensional voting space memory 112, and the space
projection unit 106 shown in FIG. 2 described above.
30 The normal flow detector 124 shown in FIG. 14 further
includes a variable histogram calculator 132 for
calculating the histogram of 1 variable of the normal
flows.

The output of the space projection unit 106
35 within the normal flow detector 124 is stored in the
two-dimensional normal flow memory 126 as the
histogram of 2 variables of the normal flows. The

1 output of the 1 variable histogram calculator 132 is
stored in the one-dimensional normal flow memory 128
as the histogram of 1 variable of the normal flows.

A description will not be repeated with
5 respect to the motion trajectory extraction unit 102,
the spatiotemporal memory 110, the Hough transform
unit 105 and the three-dimensional voting space memory
112 which were described above in conjunction with the
first embodiment of the present invention.

10 In the parameter space $S_p(\theta, \varnothing, \rho)$ formed in
the three-dimensional voting space memory 112, the
parameter θ corresponds to the direction of the normal
flow, the parameter \varnothing corresponds to the magnitude of
the velocity of the normal flow, and the parameter ρ
15 indicates the position of the corresponding contour.
Accordingly, by projecting the distribution within the
parameter space $S_p(\theta, \varnothing, \rho)$ to a space formed by the
parameters θ and \varnothing , it is possible to obtain the
histogram of 2 variables having the direction and
20 velocity of the normal flow as the parameters. For
example, a histogram $S_N(\theta, \varnothing)$ of 2 variables of the
normal flows represented by the following formula (22)
is obtained as a processed result of the space
projection unit 106.

25

$$S_N(\theta, \varnothing) = \max_{\rho} S_p(\theta, \varnothing, \rho) \quad \text{--- (22)}$$

On the other hand, a histogram S_L of 1
variable having the velocity of the normal flow as the
30 parameter can be obtained by the following formula
(23) using the histogram $S_N(\theta, \varnothing)$ of the two-
dimensional normal flows.

$$S_L(\varnothing) = \sum_{\theta} S_N(\theta, \varnothing) \quad \text{--- (23)}$$

35

In this case, a relationship described by the
following formula (24) stands between a magnitude V

1 (pixels/frame) of the velocity of the normal flow and
the parameter θ (degrees).

$$V = 1/\tan\theta \quad \text{--- (24)}$$

5

The histogram $S_N(\theta, \theta)$ of the two-
dimensional normal flows obtained in this manner is
stored in the two-dimensional normal flow memory 126
in the two-dimensional array. On the other hand, the
10 histogram $S_L(\theta)$ of the one-dimensional normal flows is
stored in the one-dimensional normal flow memory 128
in the one-dimensional array.

Next, the feature extraction unit 130
extracts the feature values of the motion included in
15 the target region of the image sequence, based on the
histograms of the 2-variable and 1-variable normal
flows stored in the two-dimensional normal flow memory
126 and the one-dimensional normal flow memory 128.
The feature extraction unit 130 supplies the extracted
20 feature values to the output unit 50.

In the fourth embodiment of the present
invention, the feature extraction unit 130 first
extracts the features related to the motion uniformity
of the target included in the target region, based on
25 the spread of the 2-variable histogram having the
direction and velocity of the normal flow as the
parameters. FIG. 15 shows the spread of the histogram
of the normal flows. In order to extract the spread
of the histogram of the normal flows such as that
30 shown in FIG. 15, the feature values of the motion
uniformity are calculated from a ratio of the maximum
value of the histogram of the normal flows and an
average value T_N or, a ratio of the maximum value of
the histogram of the normal flows and an area W_N
35 having a distribution of values greater than or equal
to the average value. More particularly, although not
limited to the following, the feature values can be

1 calculated according to f_1 through f_5 based on the
following formulas (25) through (29).

$$f_1 = [\max_{\theta, \varnothing} S_N(\theta, \varnothing)] / T_N \quad \text{--- (25)}$$

5

$$f_2 = [\max_{\theta, \varnothing} S_N(\theta, \varnothing) - T_N] / [\max_{\theta, \varnothing} S_N(\theta, \varnothing)] \quad \text{--- (26)}$$

$$f_3 = W_N \quad \text{--- (27)}$$

10

$$f_4 = [\max_{\theta, \varnothing} S_N(\theta, \varnothing)] / W_N \quad \text{--- (28)}$$

$$f_5 = [1 / \{\max_{\theta, \varnothing} S_N(\theta, \varnothing)\}] \cdot [\{\max_{\theta, \varnothing} S_N(\theta, \varnothing) - T_N\} / W_N]$$

15

--- (29)

Second, with respect to the 1-variable histogram having the velocity of the normal flow as the parameter, the motion features of the target included in the image sequence is calculated from a ratio of an accumulated value of frequencies of the velocities of the normal flows within an arbitrary interval and an accumulated value of the frequencies of the velocities of the normal flows as a whole.

25 More particularly, for example, a ratio occupied by motions having velocities greater than or equal to a velocity V_{TH} (pixels/frame) of the normal flow which is arbitrarily set with respect to the motions as a whole can be calculated from the following formula

30 (30), where $\varnothing_V = \tan^{-1} V_{TH}$.

$$f_6 = [\sum_{\varnothing \geq \varnothing_V} S_L(\varnothing)] / [\sum_{\varnothing} S_L(\varnothing)] \quad \text{--- (30)}$$

Of course, the method of extracting the feature values is not limited to the method described above.

As described above, the fourth embodiment of

1 the present invention detects the motion of the target
within the image sequence as the histogram of the
normal flows, and the feature values such as the
motion uniformity of the target within the image
5 sequence is extracted from the spread of the histogram
of the normal flows. Hence, the features related to
the complex motion caused by the appearance,
disappearance and non-rigidity of the target is
extracted from the image sequence. In addition, in
10 the fourth embodiment of the present invention, the
histogram of the normal flows is detected as the
histogram of the tangent planes tangent to the motion
trajectory which has the surface shape and is drawn
within the spatiotemporal space by the moving contour
15 of the target within the image sequence. As a result,
even under an environment in which the noise added to
the image and the appearance and disappearance of the
target occur, it is possible to stably calculate the
motion features depending on the effects of the noise,
20 appearance and disappearance.

FIG. 16 shows a functional system structure
of a fifth embodiment of the present invention. In
the fifth embodiment of the present invention,
temporal features related to the occlusion, appearance
25 and disappearance of the target are extracted. For
this reason, the tangent planes tangent to the motion
trajectory are detected from the histogram of the
tangent planes, and the distribution of the motion
trajectory on the detected tangent planes is output as
30 the image. Next, information related to the occlusion
is defined from the discontinuity or run length along
the moving direction of the motion trajectory.

The system structure shown in FIG. 16
includes an input unit 30, a processor 100, and an
35 output unit 50. The processor 100 carries out a
process of extracting the temporal features related to
the occlusion, appearance and disappearance of the

1 target, with respect to the image sequence input from
the input unit 30. The processed result of the
processor 100 is output via the output unit 50.

The processor 100 is constructed as follows.

5 A motion trajectory extraction unit 102 extracts from
the image sequence input from the input unit 30 a
target region from which the features are to be
extracted, and then extracts a motion trajectory drawn
within the spatiotemporal space by the edge and contour
10 within the target region. The motion trajectory
extracted by the motion trajectory extraction unit 102
is stored in a spatiotemporal space memory 110. The
processor 100 further includes a Hough transform unit
104 for obtaining a distribution of tangent planes
15 tangent to the motion trajectory, and a three-
dimensional voting space memory 112 for storing the
distribution of the tangent planes obtained as a
result of a Hough transform. The motion trajectory
extraction unit 102, the spatiotemporal space memory
20 110, the Hough transform unit 104 and the three-
dimensional voting space memory 112 have the same
construction and functions as the corresponding
constituent elements designated by the same reference
numerals in the system structure of the first
25 embodiment of the present invention shown in FIG. 2,
and a more detailed description of these constituent
elements will be omitted with respect to the fifth
embodiment of the present invention.

The processor 100 also includes a dynamic
30 target detector 140 for detecting a dynamic target
within the target region from the distribution of the
tangent planes stored in the three-dimensional voting
space memory 112, and outputs a distribution of the
tangent planes of this dynamic target. In addition,
35 the processor 100 is provided with a tangent plane
image extraction unit 142 for extracting a motion
trajectory distribution on the tangent planes from the

1 spatiotemporal space memory 110, and a motion
trajectory tracking unit 144 for tracking the motion
trajectory on the tangent plane image and measuring
information related to occlusion.

5 FIG. 17 shows a flow chart for explaining
the operation of the system structure of the fifth
embodiment of the present invention. The system
structure of this embodiment operates as follows.

First, in a step 50, the image sequence from
10 the input unit 30 is supplied to the motion trajectory
extraction unit 102. In a step 52, the motion
trajectory extraction unit 102 extracts from the
supplied image sequence the motion trajectory included
in the target region, and stores the motion trajectory
15 image in the spatiotemporal space memory 110. Next,
in a step 54, the Hough transform unit 104 detects the
tangent plane distribution of the motion trajectory
from the motion trajectory image stored in the
spatiotemporal space memory 110, and stores the
20 tangent plane distribution in the three-dimensional
voting space memory 112. In a step 56, the dynamic
target detector 140 detects the tangent plane
distribution related to the dynamic target within the
target region, from the tangent plane distribution
25 stored in the three-dimensional voting space memory
112. Next, in a step 58, the tangent plane image
extraction unit 142 extracts as the image the planar
motion trajectory distribution related to the detected
tangent planes. In a step 60, the motion trajectory
30 tracking unit 144 tracks the motion trajectory on the
extracted image, measures occlusion information, and
supplies the measured result to the output unit 50.
Finally, in a step 62, the output unit 50 outputs the
occlusion information obtained from the motion
35 trajectory tracking unit 144.

Next, a more detailed description will be
given of the functions of the processor 100. As

1 described above, the motion trajectory extraction unit
102, the spatiotemporal space memory 110, the Hough
transform unit 104 and the three-dimensional voting
space memory 112 were described in detail in
5 conjunction with the first embodiment of the present
invention. Hence, a description will hereunder be
given of the dynamic target detector 140, the tangent
plane image extraction unit 142 and the motion
trajectory tracking unit 144.

10 The dynamic target detector 140 detects the
dynamic target within the target region, from the
tangent plane distribution stored in the three-
dimensional voting space memory 112, and operates so
as to output the tangent plane distribution of the
15 dynamic target. In the fifth embodiment of the
present invention, attention is drawn particularly to
the target which makes a translation motion at the
same velocity and in the same direction within the
target region. The velocity components of the target
20 are estimated, and the tangent plane distribution
originating from the target having the estimated
velocity components is acquired.

Accordingly, in the case where the target
translates in the same direction at the same velocity,
25 the fifth embodiment of the present invention utilizes
the characteristic that the directions of the
intersection lines of the tangent planes all match the
directions of the target motion. In addition, among
the intersection lines formed by the combination of
30 all of the tangent planes, the direction of the most
conspicuous intersection line is acquired as the most
dominant translational velocity component within the
target region.

FIG. 18 shows the construction of the
35 dynamic target detector 140 which realizes the above
described operation, that is, acquires the most
dominant translational velocity component within the

1 target region from the tangent plane distribution
stored in the three-dimensional voting space memory
112. As shown in FIG. 18, the dynamic target detector
140 includes a space projection unit 106, a normal
5 parameter space memory 114, an intersection histogram
obtaining unit 150, an intersection histogram memory
151, and a translational velocity estimation unit 152.

The above described dynamic target detector
140 may be constructed similarly to the construction
10 which is realized in a part of the system structure of
the second embodiment of the present invention
describe above in conjunction with FIGS. 6 and 7.
Accordingly, no further description will be given of
each of the constituent elements of the dynamic target
15 detector 140.

As already described above with respect to
the second embodiment of the present invention, the
translational velocity estimation unit 152 detects the
peak in the vote distribution within the intersection
20 parameter space S_L , and obtains the most dominant
translational velocity component of the target object
within the target region from the coordinate values
(α_p , β_p) of the detected peak. The direction of the
motion is obtained as

25
$$\alpha_p \quad \text{--- (31)}$$

and a magnitude V of the velocity is obtained by the
following formula (32).

30
$$V = 1/\tan\beta_p \quad \text{--- (32)}$$

Next, with respect to the dynamic target
having such a velocity component detected within the
35 target region, the distribution of the tangent planes
tangent to the motion trajectory of the contour of
this dynamic target is considered. When the

1 translational velocity component of the dynamic target
within the target region is denoted by the
intersection line direction (α_p, β_p) , a relationship
described by the following formula (33) stands between
5 the parameters θ and \varnothing in the normal directions of the
tangent planes, as described above.

$$\varnothing = -\tan^{-1}\{\tan\beta_p/\cos(\alpha_p-\theta)\} \quad \text{--- (33)}$$

10 From the formula (33), it may be seen that
the distribution of the tangent planes to be acquired
exists on a cylinder having the curve described by the
formula (33) as the base curve of the cylinder, within
the plane parameter space $S_p(\theta, \varnothing, \rho)$ which is a
15 three-dimensional space.

The tangent plane image extraction unit 142
extracts as an image the motion trajectory
distribution on the tangent planes from the tangent
plane distribution of the motion trajectory drawn by
20 the contour and edge having the translational velocity
estimated by the dynamic target detector 140. A
description will now be given of a particular example
in the fifth embodiment of the present invention.

A case will be considered where occlusion
25 information related to the contour and edge having the
tangent line direction θ' is obtained. The parameter
 \varnothing determined by the relationship described by the
formula (33) is denoted by \varnothing' . In addition, when the
histogram $S_p(\theta', \varnothing', \rho)$ of the tangent planes is
30 searched in the ρ direction, and the parameter ρ
corresponding to the peak in the histogram
 $S_p(\theta', \varnothing', \rho)$ is denoted by ρ' . One tangent plane is
determined by parameters $(\theta', \varnothing', \rho')$. Coordinates on
the tangent planes are described by vectors in 2
35 directions, namely, the moving direction and the
tangent line direction of the contour and edge. A
vector V in the moving direction is described by the

1 following formula (34), while a tangent line vector p_s
of the contour and edge is described by the following
formula (35).

5
$$V = (V_x, V_y, V_z)$$
$$= (\cos\alpha_p \cdot \cos\beta_p, \sin\alpha_p \cdot \cos\beta_p, \sin\beta_p) \quad \text{--- (34)}$$

$$p_s = (-\sin\theta', \cos\theta', 0) \quad \text{--- (35)}$$

10 In addition, a vertical vector p_o from the
origin within the target region to the tangent plane
can be described by the following formula (36) using
the formula (2) of the polar coordinates.

15
$$p_o = \rho' \cdot (\cos\theta' \cdot \sin\phi', \sin\theta' \cdot \sin\phi', \cos\phi')$$
$$\quad \text{--- (36)}$$

Accordingly, a position vector $z(s, l)$ on
the tangent plane can be described by the following
20 formula (37), where l denotes a parameter of the
moving direction (time), and s denotes a parameter of
the tangent line direction (space) of the contour.

$$z(s, l) = s \cdot p_s + l \cdot V + p_o \quad \text{--- (37)}$$

25

Next, when the spatiotemporal difference
image $D(x, y, t)$ stored in the spatiotemporal space
memory 110 is cut out at the tangent plane of the
formula (37) as the three-dimensional volume data, a
30 cross sectional image obtained thereby is acquired as
a tangent plane image $Z(s, l)$ which is described by
the following formula (38). In this tangent plane
image $Z(s, l)$, the motion trajectory of 1 point on the
contour moves in the positive direction along l axis.

35

$$Z(s, l) = (D(z(s, l))) = (D(s \cdot p_s + l \cdot V + p_o)) \quad \text{--- (38)}$$

1 Next, the motion trajectory tracking unit
144 obtains the motion trajectory distribution on the
tangent planes extracted as the image in the tangent
plane image extraction unit 142, tracks the moving
5 direction, and measures information related to the
occlusion. For example, in the fifth embodiment of
the present invention, the motion trajectory tracking
unit 144 operates as follows.

First, the following method is employed as
10 an example of a method for judging the existence of
the occlusion. In the tangent plane image $Z(s, l)$,
the motion trajectory distribution is checked along 1
axial direction with respect to each s . With respect
to s for which the motion trajectory exists, an
15 attempt is made to detect a position where the motion
trajectory is interrupted. When no interruption of
the motion trajectory is detected within the target
region of the target tangent plane image, it is judged
that no occlusion exists within the target region. On
20 the other hand, it is judged that the occlusion exists
within the target region when the interruption of the
motion trajectory is detected.

In order to obtain information related to
the degree of occlusion, a reference is made to the
25 distribution of the motion trajectory along 1 axial
direction in the tangent plane image $Z(s, l)$ for each
 s , and a run length of the motion trajectory from the
appearance to the disappearance is measured. An
average value of this run length is output as the
30 degree of occlusion. When the average run length is
long, it may be judged that the occlusion is small.
On the other hand, it may be judged that the occlusion
is large when the average run length is short. For
example, when the average run length on the tangent
35 plane image is denoted by LENGTH, a distance DIST for
which the target appears on the image plane can be
described by $DIST = (LENGTH) \cdot \cos\theta$.

1 Furthermore, a description will now be given
of an example of a method for acquiring information
related to starting point and terminal point positions
of the occlusion.

5 In the tangent plane image $Z(s, l)$, the
motion trajectory along l axial direction is checked
for each s , and a position (s_d, l_d) where the motion
trajectory disappears is detected within the tangent
plane image range included in the target region.
10 Hence, it is possible to know the starting point of
the occlusion. A spatial position within the
spatiotemporal coordinates corresponding to the
position (s_d, l_d) obtained from the formula (38)
indicates the position on the image plane. Similarly,
15 it is possible to know the position of the terminal
point of the occlusion by detecting the position $(s_d,$
 $l_d)$ where the motion trajectory appears.

As described above, according to the fifth
embodiment of the present invention, the motion
20 trajectory drawn within the spatiotemporal space by
the contour and edge of the target which moves within
the image sequence is extracted when measuring
information related to the existence, frequency and/or
position of the occlusion which has a possibility of
25 occurring with respect to the dynamic target included
within the image sequence. Next, the histogram of the
tangent planes tangent to the extracted motion
trajectory is acquired, and the motion trajectory
distribution on the acquired tangent planes is
30 extracted as the image. By measuring the
intermittence of the motion trajectory in the moving
direction with respect to this extracted image, it is
possible to obtain information related to the
occlusion of the target. Therefore, in a situation
35 where the occlusion exists, the dynamic target is
stable tracked, and it is possible to accurately
obtain the information related to the occlusion.

1 Next, a description will be given of various
modifications of the first through fifth embodiments
of the present invention described above.

Modification 1:

5 In the embodiments described above, the
Hough transform is used when obtaining the histogram
of the tangent planes tangent to the motion trajectory
from the motion trajectory which is structured as the
three-dimensional volume data. However, the present
10 invention is not limited to the use of the Hough
transform. A description will be given of another
method of obtaining from the motion trajectory the
histogram of the tangent planes tangent to the motion
trajectory. A histogram extraction unit which is
15 constructed to realize this other method may be used
in place of the Hough transform unit.

A normal vector (D_x , D_y , D_t) of the tangent
plane tangent to the motion trajectory passing a
certain point (x_1 , y_1 , t_1) within a spatiotemporal
20 difference image $D(x, y, t)$, can be calculated from
the following formulas (39) through (41) as
differences between adjacent pixels. Of course,
differences between other adjacent pixels may be used.

25 $D_x = D(x_1+1, y_1, t_1) - D(x_1, y_1, t_1)$ --- (39)

$D_y = D(x_1, y_1+1, t_1) - D(x_1, y_1, t_1)$ --- (40)

$D_t = D(x_1, y_1, t_1+1) - D(x_1, y_1, t_1)$ --- (41)

30

Next, a unit normal vector (n_x , n_y , n_t)
which is obtained by normalizing the magnitude of the
normal vector (D_x , D_y , D_t) to 1 is calculated from the
following formulas (42) through (44).

35

$n_x = D_x / [D_x^2 + D_y^2 + D_t^2]^{\frac{1}{2}}$ --- (42)

$$1 \quad n_y = D_y / [D_x^2 + D_y^2 + D_t^2]^{\frac{1}{2}} \quad \text{--- (43)}$$

$$n_t = D_t / [D_x^2 + D_y^2 + D_t^2]^{\frac{1}{2}} \quad \text{--- (44)}$$

5 Generally, an equation of a plane which passes the point (x_1, y_1, t_1) and has the unit normal vector (n_x, n_y, n_t) can be described by the following formula (45).

$$10 \quad n_x(x-x_1) + n_y(y-y_1) + n_t(t-t_1) = 0 \quad \text{--- (45)}$$

 Accordingly, the parameters θ , \varnothing and ρ of the polar coordinate representation of the plane can be calculated from the following formulas (46) through
15 (48) based on the relationship to the equation of the plane using these parameters.

$$\theta = \tan^{-1}(n_y/n_x) \quad \text{--- (46)}$$

$$20 \quad \varnothing = \cos^{-1} n_t \quad \text{--- (47)}$$

$$\rho = n_x x_1 + n_y y_1 + n_t t_1 \quad \text{--- (48)}$$

 Accordingly, with respect to each point $(x_1,$
25 $y_1, t_1)$ within the spatiotemporal difference image $D(x, y, t)$, it is possible to calculate the parameters $(\theta, \varnothing, \rho)$ of the tangent planes on the motion trajectory. For this reason, the histogram of the tangent planes is secured as a three-dimensional array
30 by making discrete the parameter space formed by the parameters of the tangent planes. Then, the values of all elements in the three-dimensional array are initialized to 0. The parameters $(\theta, \varnothing, \rho)$ of the tangent planes are calculated for each element $(x_1,$
35 $y_1, t_1)$ of the spatiotemporal difference image $D(x, y, t)$, and the values of $D(x_1, y_1, t_1)$ are added to each element of the array in the corresponding parameter

1 spaces. After such an operation is carried out with
respect to the pixels within all of the spatiotemporal
difference images, the parameter spaces are obtained
as the histogram of the tangent planes.

5 This method described above obtains the
normal direction of the tangent plane from the gray
level difference of the adjacent pixels within the
spatiotemporal difference image. For this reason,
this method may be considered as being more sensitive
10 to external disturbances such as noise as compared to
the method employing the three-dimensional Hough
transform.

Modification 2:

In the second embodiment of the present
15 invention, extracting the distribution of the tangent
planes along the tangent line direction of the
contour, the distribution CC used to represent the
histogram of the tangent line direction of the contour
may be calculated from formulas other than the formula
20 (15) described above, such as the following formula
(49) or (50), where A denotes an average value of the
distribution CS in the ρ direction, and $W_{CS}(\theta)$ denotes
a number of cells having values greater than or equal
to an average value A when the distribution CS is
25 checked in an order in the ρ direction.

$$CC(\theta) = \max_{\rho} CS(\theta, \rho) - A \quad \text{--- (49)}$$

$$CC(\theta) = [\max_{\rho} CS(\theta, \rho) - A] / W_{CS}(\theta) \quad \text{--- (50)}$$

30

In addition, the uniformity of the contour
or, the strength of the directionality, is defined by
the formula (16) in the second embodiment of the
present invention, but may be defined by the following
35 formula (51), where W_H denotes a number of cells of an
arrangement $CC(\theta)$ having a value greater than or equal
to an average value \overline{CC} .

1

$$f_1 = [1/W_H] \cdot [\{\max_{\theta} CC(\theta) - \overline{CC}\} / \{\max_{\theta} CC(\theta)\}]$$

--- (51)

5

Furthermore, instead of using the formula (17) to define the concentration of the contour in the tangent line direction θ , it is possible to use the following formula (52).

10

$$f_2(\theta) = A / [\max_{\varphi} CS(\theta, \varphi)]$$

--- (52)

15

For example, assume a case where the gray level values of all edges are the same and have an impulse shape. In this case, when the contour (edge) parallel to the tangent line direction θ of a certain contour is considered, the number of contours (edges) per unit pixel in this case corresponds to the definition of the concentration of the contour. When only 1 contour exists, the concentration becomes a minimum, and the concentration increases as the number of contours increases. The concentration becomes a maximum when the edge exists at all of the pixels. In this state, all of the pixels are filled, and the edge in the direction θ is not visible.

25

The value of $CC(\theta)$ may be used as a feature value indicating the degree of scattering or the degree of coarseness, and having a meaning opposite to the concentration.

30

Instead of the repetition f_3 of the entire contour defined in the second embodiment of the present invention, it is also possible to use a minimum value of $f_2(\theta)$ as the feature value representing the concentration of the entire pattern, as indicated by the following formula (53).

35

$$f_3 = \min_{\theta} f_2(\theta)$$

--- (53)

1 In addition, the degree of scattering of the
entire pattern may be defined by a maximum value
 $\max_{\theta} CC(\theta)$, as another feature value.

5 Modification 3:

In the fourth embodiment of the present invention, when obtaining the histogram of the normal flows from the histogram of the tangent planes or partial planes, the formula (22) is used as the 2-
10 variable histogram $S_N(\theta, \varphi)$ of the normal flows. However, it is possible to use the definition of the following formula (54) or (55) in place of the formula (22), where A denotes an average value of S_p in the ρ direction.

$$S_N(\theta, \varnothing) = \max_{\rho} S_P(\theta, \varnothing, \rho) - A(\theta, \varnothing) \quad \text{--- (54)}$$

$$S_N(\theta, \varnothing) = [\max_{\varphi} S_P(\theta, \varnothing, \varphi) - A(\theta, \varnothing)] / [\max_{\varphi} S_P(\theta, \varnothing, \varphi)] \quad (55)$$

In this case, the average value A can be calculated from the following formula (56), where N_φ denotes a number of divisions of the array S_p in the φ direction, that is, the number of cells. When calculating the histogram of the tangent planes using the three-dimensional Hough transform as in the fourth embodiment of the present invention, this average value $A(\theta, \varphi)$ is a constant value independent of θ and φ .

$$A(\theta, \varnothing) = \sum_{\rho} S_P(\theta, \varnothing, \rho) / N \quad \text{--- (56)}$$

Modification 5:

35 In the second embodiment of the present
invention, the tangent plane corresponding to the
estimated velocity component is extracted when

1 specifying the tangent plane from the histogram of the
tangent planes. However, it is possible to employ
other methods, such as a method which searches for a
local maximum in the tangent plane distribution.

5 Next, a description will be given of
applications of the first through fifth embodiments of
the present invention to a weather radar image
sequence obtained from a weather radar equipment.

Application 1: Application of the first
10 embodiment of the present invention

FIGS. 19A through 19C show patterns having 3
different features in a part within a frame of the
weather radar image sequence obtained from the weather
radar equipment. FIG. 19A shows a stagnating
15 stratiform pattern, wherein random luminance change on
the image surface is more conspicuous than the motion
component. FIG. 19B shows a band-shaped pattern in
which radar echo flows in a band shape. Each echo
cell has a life cycle, and the band-shaped pattern is
20 maintained by the regular occurrence of the appearance
and disappearance of a plurality of echo cells. FIG.
19C shows a scattered pattern in which both the shape
and arrangement of the echo are scattered at random.
In FIGS. 19A through 19C, the target region is
25 indicated by a square frame within the image. 20
successive frames were used for each of the patterns
shown in FIGS. 19A through 19C.

FIGS. 20A through 20C show distributions of
the motion trajectories respectively generated by the
30 motion trajectory extraction unit 102 from the image
sequences shown in FIGS. 19A through 19C and
accumulated in the spatiotemporal space memory 110.
It may be seen from FIGS. 20A through 20C that motion
trajectories having different features are obtained
35 with respect to the 3 patterns shown in FIGS. 19A
through 19C.

FIGS. 21A through 21C respectively show

1 results obtained by carrying out the three-dimensional
Hough transform by the Hough transform unit 104 with
respect to the motion trajectories shown in FIGS. 20A
through 20C and then projecting the results of the
5 three-dimensional Hough transform to the two-
dimensional space by the space projection unit 106.
FIGS. 21A through 21C respectively correspond to the
vote distributions accumulated in the normal parameter
space memory 114 with respect to the image sequences
10 shown in FIGS. 19A through 19C. At each point in
FIGS. 21A through 21C, a white point indicates a large
vote, and a black point indicates a small vote.

The distribution shown in FIG. 21A has a
gradual peak, and the votes are distributed over a
15 wide range. This means that velocity components
having a certain directionality exist, and that the
effects of the appearance and disappearance at the
surface are large. On the other hand, conspicuous
peaks linked in an arcuate shape can be observed in
20 the distribution shown in FIG. 21B. It can be seen
that FIG. 21B corresponds to the distribution of the
tangent planes surrounding the cylindrical motion
trajectory, and that a conspicuous translational
velocity component exists in the target motion. In
25 addition, the votes are distributed over a wide range
in the bottom portion of FIG. 21B and indicate the
effects of the appearance and disappearance of the
echo cells. Furthermore, a peak of the vote
concentrated at one location can be observed in the
30 distribution shown in FIG. 21C. This means that echo
cells having a relatively flat edge move at a uniform
velocity without appearing and disappearing.

FIG. 22 shows the most dominant
translational velocity component within the target
35 region obtained by the feature extraction unit 108.
The direction of the velocity is indicated by 0 degree
for the direction from left to right, and the angle

1 increases counterclockwise.

Therefore, according to the application of the first embodiment of the present invention, the features related to the shape and motion of the target within the image sequence are represented as the shape of the vote distribution as shown in FIGS. 21A through 21C. Hence, by observing the difference among the shapes of the vote distributions, it is possible to judge the temporal features and the spatial features of the image sequence. For this reason, the system structure of the first embodiment of the present invention may be utilized for classifying and searching a pattern in the image sequence. In addition, it is possible to objectively extract the vote distribution by the feature extraction unit 108, so that it is possible to realize an automatic classification of the image sequence. Furthermore, with respect to the weather radar images shown in FIGS. 19A through 19C, it is possible to apply the present invention to weather forecast by referring to past weather radar images similar to the present weather conditions.

Application 2: Application of the second embodiment of the present invention

25 FIG. 23 shows 1 frame of the image sequence when the second embodiment of the present invention is applied. This frame includes a scene having 3 contours which form curves and move uniformly from the left to right. FIG. 24 shows a histogram of the tangent planes on the constraint surface which is obtained with respect to this image sequence. In FIG. 24, it is possible to observe the tangent plane distributions CS having curved shapes corresponding to the 3 contours.

35 FIG. 25 shows a tangent line direction histogram CC acquired from the tangent plane distributions CS described above according to the

1 method employed in the second embodiment of the
present invention. From FIG. 25, it is possible to
confirm the existence of peaks which spread in
correspondence with the directions of the contours
5 forming the curves. However, the distribution itself
of the peaks is not smooth due to the effects of the
discretization of the image. The uniformity f_1 in the
contour direction obtained from this distribution of
the peaks is 0.01.

10 FIG. 26 shows an example of the distribution
in the direction of the tangent plane distributions
CS for $\theta = 0$ (horizontal direction). In this case,
the repetition f_2 in the contour direction is 0.91.

Application 3: Application of the third
15 embodiment of the present invention

FIGS. 27A through 27C are diagrams for
explaining the process carried out by the third
embodiment of the present invention. A case will be
considered where 2 objects having different motions
20 within the image sequence exist as shown in FIG. 27A.
In this particular case, a circle which moves 1
(pixel/frame from the right to left, and a circle
which moves 1 (pixel/frame) from the bottom to top
exist. FIG. 27B shows the tangent plane distributions
25 $S_N(\theta, \phi)$ (= normal parameter space) of the trajectory
surface of the moving objects, with respect to the
image sequence shown in FIG. 27A. It may be observed
from FIG. 27B that the distributions of the tangent
planes in the periphery of the contours of the 2
30 moving objects appear as 2 curved distributions. FIG.
27C shows a histogram of the intersection directions
obtained from the tangent plane distributions shown in
FIG. 27B. It is possible to clearly observe the
existence of 2 different peaks from FIG. 27C. The
35 positions of the 2 peaks can be obtained as $(\alpha_1, \beta_1) =$
 $(0, 45)$ (deg) and $(\alpha_2, \beta_2) = (90, 45)$ (deg). With
respect to the 2 peak positions, it is possible to

1 obtain the velocity components of the 2 moving objects
as $v_1 \sim (1, 0)$ (pixel/frame) and $v_2 = (0, 1)$
(pixel/frame) based on the formulas (20) and (21). In
this particular case, it is unnecessary to take into
5 consideration the composite velocity component because
only 2 peaks exist.

Application 4: Application of the fourth
embodiment of the present invention

An image sequence pattern will be considered
10 in which cells arranged in a lattice as shown in FIG.
28A move uniformly at a velocity of $\sqrt{2}$ (pixels/frame)
towards the top right direction. In this basic
pattern, it may be evaluated that the motion
uniformity is high because all of the image elements
15 move uniformly. In addition, FIG. 28B shows an image
sequence pattern obtained by adding contrasting random
noise with respect to the basic pattern. Since the
random noise are distributed at random in all of the
frames, the random noise have various complex motions
20 completely different from the motion of the basic
lattice pattern.

FIGS. 29A and 29B respectively show the
histograms of the normal flows with respect to the
patterns shown in FIGS. 28A and 28B. The gray level
25 of each point in the images shown in FIGS. 29A and 29B
correspond to the histograms of the normal flows, and
the frequency is higher for points which are more
white. The distribution which spreads in a curve and
is seen at the central part of FIG. 29A corresponds to
30 the normal flow components of the basic pattern shown
in FIG. 28A. In this case, only the points on the
curve have extremely high values as compared to the
points at other portions. For this reason, the
feature values f_1 through f_5 of the motion uniformity
35 described by the formulas (25) through (29) show high
values. On the other hand, in FIG. 29B, not only the
distribution having the curved shape and corresponding

1 to the normal flow components of the basic pattern,
but also the normal flow components corresponding to
the random noise added to the image are widely spread
in various directions and at various velocities. For
5 this reason, the feature values of the motion
uniformity show low values in the case shown in FIG.
28B as compared to the case shown in FIG. 28A where
only the basic pattern exists.

FIG. 30 shows a change in the feature values
10 of the motion uniformity in a case where an amount of
random noise added to the image is changed. In this
particular case, f_5 described by the formula (29) is
used as the feature value of the motion uniformity.
In FIG. 30, the abscissa indicates a ratio of the
15 number of pixels added with the random noise with
respect to the total number of pixels in the image.
From FIG. 30, it may be observed that the motion
uniformity decreases as the ratio of the noise
increases.

20 Application 5: Application of the fifth
embodiment of the present invention

A scene will be considered of in which a
target moves from the left to right as shown in FIG.
31A. In this state, if an occluding object shown in
25 FIG. 31B is interposed between the target and an
observer, an image shown in FIG. 31C is observed by
the observer. A motion trajectory drawn by a portion
of the contour of the target in this case is shown in
FIG. 31D. When the motion trajectory on the tangent
30 plane shown in FIG. 31D is extracted, an intermittent
motion trajectory distribution shown in FIG. 31E is
obtained. Since the occluding object is represented
as a discontinuous motion trajectory, it is possible
to judge the degree of the occlusion by making a
35 search on the tangent plane image in 1 direction and
measuring the run length of the motion trajectory.

Application 6: Particular field of

1 application

As applications which use the image features extracted by the present invention, there are supports associated with the monitoring of the weather

5 phenomenon using the weather radar image, the weather forecast using search and classification of the weather radar image, and the analysis of the weather phenomenon.

The weather radar image is obtained by
10 visualizing the radar echo reflection intensity obtained by the weather radar equipment. The weather radar image includes a pattern called the echo pattern, and represents a spatial distribution of the precipitation intensity. When observations are made
15 at constant time intervals, it is possible to obtain a sequence of images. The echo pattern is a non-rigid body which appears, disappears and deforms, and has a shape, pattern and motion peculiar to each precipitation phenomenon.

20 For example, as often seen in the Japan Sea and the Gulf of Mexico during the winter time, when a roll-shaped convection occurs due to the monsoon wind from the continent, the band-shaped echo pattern shown in FIG. 19B appears on the weather radar image. In
25 addition, when a low (atmospheric) pressure approaches, the stratiform echo pattern shown in FIG. 19A appears at the front part of the low pressure.

In the band-shaped echo pattern, small image elements called echo cells move along the atmospheric
30 flow, thereby forming several bands. Each echo cell has a life cycle peculiar thereto, including appearance, growth and decay. In addition, the stratiform echo pattern has a relatively large area and a misty surface, and the pattern thereof changes
35 at a high speed.

The feature values can be calculated using the method and equipment of the present invention, by

- 1 inputting the weather radar image sequence obtained by
observing the above described whether phenomena. As a
result, the difference among the echo patterns is
reflected as a difference among the feature values.
- 5 For example, the feature value of the motion
uniformity becomes larger in the case of the band-
shaped echo as compared to the stratiform echo
pattern, and the ratio of the high-velocity components
becomes larger in the case of the stratiform echo
10 pattern as compared to the band-shaped echo pattern.

Accordingly, echo patterns corresponding to
several typical weather phenomena are selected from
the past weather radar images, and the feature values
obtained from the selected echo patterns are stored in
15 advance. By comparing the feature values which are
calculated from the newly obtained weather radar image
with the stored feature values, it is possible to
judge a past weather phenomenon which includes echo
patterns closest to the echo patterns of the newly
20 input weather image. As a result, it becomes possible
to automatically monitor the weather phenomenon, and
the present invention may be used as a tool for
analyzing the weather phenomenon.

In addition, by constructing a database
25 which accumulates the past weather radar images and
the feature values at each point in time, it is
possible to use the feature values obtained from the
most recent weather radar image as keys to retrieve a
past weather radar image which most resembles the
30 feature values. In this case, it is possible to
retrieve a weather radar image which comprehends a
phenomenon similar to the present weather phenomenon.
Next, by providing changes in the retrieved weather
radar image with time with respect to a user such as a
35 meteorologist, it is possible to support the weather
forecast.

The present invention may be realized in the

1 form of a computer or an apparatus similar to a
computer which is used as a hardware platform. The
computer in this case includes a storage unit such as
a hard disk unit capable of freely storing data and
5 reading the data, a unit such as a buffer which is
used when processing the data, an output unit such as
a display unit and a file unit for displaying or
outputting desired information, and a central
processing unit for controlling the storage unit, the
10 unit such as the buffer and the output unit based on a
predetermined procedure. All or a portion of the
process carried out by the system structure of the
various embodiments of the present invention described
above may be realized by providing a program or the
15 like containing algorithms of the process to the
hardware platform, and controlling the hardware
platform to execute the program. The program or the
like may be recorded, provided and distributed in the
form of a ROM, memory card, CD-ROM, floppy disk (FD),
20 magneto-optic disk (MO), DVD and other computer-
readable recording mediums suited for storing the
program.

Further, the present invention is not
limited to these embodiments, but various variations
25 and modifications may be made without departing from
the scope of the present invention.

30

35

1 WHAT IS CLAIMED IS

5

1. A method for extracting image features from an image sequence in which frames indicating images are time-sequentially arranged with respect to time, said method comprising the steps of:

10 (a) inputting the image sequence;

(b) acquiring a motion trajectory of an image contour of a target included within a region defined by an arbitrary spatial range and time range within the image sequence input by said step (a), as three-
15 dimensional volume data drawn within a spatiotemporal space in which each of the frames is time-sequentially stacked; and

(c) measuring temporal features and spatial features of the image from the motion trajectory which
20 is acquired as the three-dimensional volume data by said step (b).

25

2. A method for extracting image features from an image sequence in which frames indicating images are time-sequentially arranged with respect to time, said method comprising the steps of:

30 (a) inputting the image sequence;

(b) acquiring a motion trajectory of an image contour of a target included within a region defined by an arbitrary spatial range and time range within the image sequence input by said step (a), as three-
35 dimensional volume data drawn within a spatiotemporal space in which each of the frames is time-sequentially stacked;

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- 1 (c) acquiring a plane histogram of one of
tangent planes tangent to the motion trajectory and
partial planes which may be included in the motion
trajectory; and
- 5 (d) measuring temporal features and spatial
features of the image from the plane histogram which
is acquired by said step (c).

10

3. A method for extracting image features
from an image sequence in which frames indicating
images are time-sequentially arranged with respect to
15 time, said method comprising the steps of:

- (a) inputting the image sequence;
- (b) acquiring a motion trajectory of an image
contour of a target included within a region defined
by an arbitrary spatial range and time range within
20 the image sequence input by said step (a), as three-
dimensional volume data drawn within a spatiotemporal
space in which each of the frames is time-sequentially
stacked;
- (c) acquiring a plane histogram of tangent
25 planes tangent to the motion trajectory;
- (d) estimating a velocity component of the
target which moves within the region from the plane
histogram acquired by said step (c);
- (e) extracting a distribution of the tangent
30 planes corresponding to the image contour of the
target which moves at the velocity component estimated
by said step (d), from the plane histogram acquired by
said step (c); and
- (f) acquiring spatial features of the image from
35 the distribution of the tangent planes extracted by
said step (e).

1 4. The method as claimed in claim 3,
wherein said step (d) includes the substeps of:
 (d1) acquiring a histogram of intersection lines
of the tangent planes from the plane histogram
5 acquired by said step (c); and
 (d2) acquiring, as image features, a most
dominant translational velocity component of the
target which moves within the defined region, from the
histogram of the intersection lines acquired by said
10 substep (d2).

15 5. The method as claimed in claim 3,
wherein said step (d) includes the substeps of:
 (d1) acquiring a histogram of intersection lines
of the tangent planes from the plane histogram
acquired by said step (c); and
20 (d2) detecting a plurality of peaks from the
histogram of the intersection lines acquired by said
substep (d1);
 (d3) acquiring velocity components of a plurality
of motions within the region corresponding to the
25 plurality of peaks detected by said substep (d2); and
 (d4) judging whether or not each of the velocity
components can be represented by a composite velocity
of other velocity components, with respect to the
velocity components acquired by said substep (d3), and
30 outputting an independent velocity component which
cannot be represented by the composite velocity of the
other velocity components.

35

6. The method as claimed in claim 3,

1 wherein said step (e) extracts a distribution of
tangent planes along tangent line directions to the
image contour of the target, and said step (f)
calculates feature values related to a directionality
5 of the image contour of the target from the
distribution of the tangent planes extracted by said
step (e).

10

7. The method as claimed in claim 3,
wherein said step (e) extracts a distribution of
tangent planes in directions perpendicular to a
15 direction of the image contour of the target, and said
step (f) extracts features related to a spatial
arrangement of the image contour of the target.

20

8. A method for extracting image features
from an image sequence in which frames indicating
images are time-sequentially arranged with respect to
25 time, said method comprising the steps of:

(a) inputting the image sequence;
(b) acquiring a motion trajectory of an image
contour of a target included within a region defined
by an arbitrary spatial range and time range within
30 the image sequence input by said step (a), as three-
dimensional volume data drawn within a spatiotemporal
space in which each of the frames is time-sequentially
stacked;

(c) acquiring a plane histogram of tangent
35 planes tangent to the motion trajectory;

(d) acquiring a histogram of intersection lines
of the tangent planes from the plane histogram

1 acquired by said step (c);

(e) detecting a plurality of peaks from the histogram of the intersection lines acquired by said step (d); and

5 (e) acquiring a plurality of velocity components of motions within the region corresponding to the plurality of peaks detected by said step (e).

10

9. The method as claimed in claim 8, which further comprises the steps of:

(f) judging whether or not each of the velocity
15 components can be represented by a composite velocity of other velocity components, with respect to the plurality of velocity components acquired by said step (e); and

(g) outputting an independent velocity component
20 which cannot be represented by the composite velocity of the other velocity components.

25

10. A method for extracting image features from an image sequence in which frames indicating images are time-sequentially arranged with respect to time, said method comprising the steps of:

30 (a) inputting the image sequence;

(b) acquiring a motion trajectory of an image contour of a target included within a region defined by an arbitrary spatial range and time range within the image sequence input by said step (a), as three-
35 dimensional volume data drawn within a spatiotemporal space in which each of the frames is time-sequentially stacked;

- 1 (c) acquiring a plane histogram of one of
tangent planes tangent to the motion trajectory and
partial planes which may be included in the motion
trajectory;
- 5 (d) acquiring a normal flow histogram of normal
flows of the image from the plane histogram acquired
by said step (c); and
- (e) acquiring temporal features of the image
from the normal flow histogram acquired by said step
- 10 (d).

15 11. The method as claimed in claim 10,
wherein said step (d) acquires a normal flow histogram
having direction and velocity of the normal flows as
variables, and said step (e) calculates spreading of
the normal flow histogram as feature values

20 representing motion uniformity of the image.

25 12. The method as claimed in claim 10,
wherein said step (d) acquires a normal flow histogram
having velocity of the normal flows as a variable, and
said step (e) calculates a ratio of totalled frequency
value corresponding to normal flows having specific

30 velocities with respect to a totalled frequency value
as a whole as feature values representing the motion
of the image.

35

13. A method for extracting image features

1 from an image sequence in which frames indicating
images are time-sequentially arranged with respect to
time, said method comprising the steps of:
 (a) inputting the image sequence;
5 (b) acquiring a motion trajectory of an image
contour of a target included within a region defined
by an arbitrary spatial range and time range within
the image sequence input by said step (a), as three-
dimensional volume data drawn within a spatiotemporal
10 space in which each of the frames is time-sequentially
stacked;
 (c) detecting tangent planes tangent to the
motion trajectory;
 (d) extracting, as an image, a distribution of
15 the motion trajectory existing on the tangent planes
detected by said step (c); and
 (e) tracking a motion trajectory on the image
extracted by said step (d) and detecting an occlusion
of the target.
20

14. The method as claimed in claim 13,
25 wherein said step (e) includes the substeps of:
 (e1) measuring intermittence along a moving
direction of the motion trajectory; and
 (e2) detecting the occlusion of the target based
on the intermittence measured by said substep (e1).
30

15. The method as claimed in claim 13,
35 wherein said step (e) includes the substeps of:
 (e1) measuring statistics of a run length along a
moving direction of the motion trajectory; and

1 (e2) detecting a degree of the occlusion of the
target from the statistics of the run length measured
by said substep (e1).

5

16. The method as claimed in claim 13,
wherein said step (c) detects the tangent planes in a
10 form of a histogram of the tangent planes which are
represented as a distribution of votes accumulated in
a plane parameter space obtained by use of a three-
dimensional Hough transform.

15

17. The method as claimed in claim 13,
wherein said step (c) detects tangent planes
20 corresponding estimated velocity components.

25 18. The method as claimed in any of claims
1, 2, 3, 8, 10 and 13, wherein the three-dimensional
volume data is obtained by forming difference images
among the frames in time sequence, and stacking the
formed difference images.

30

19. The method as claimed in any of claims
35 2, 3, 8 and 10, wherein the plane histogram is
obtained as votes accumulated in a plane parameter
space obtained by use of a three-dimensional Hough

1 transform.

5

20. An equipment for extracting image features from an image sequence in which frames indicating images are time-sequentially arranged with respect to time, said equipment comprising:

- 10 first means for inputting the image sequence;
second means for acquiring a motion trajectory of an image contour of a target included within a region defined by an arbitrary spatial range and time range within the image sequence input by said first means,
15 as three-dimensional volume data drawn within a spatiotemporal space in which each of the frames is time-sequentially stacked; and
third means for measuring temporal features and spatial features of the image from the motion
20 trajectory which is acquired as the three-dimensional volume data by said second means.

25

21. An equipment for extracting image features from an image sequence in which frames indicating images are time-sequentially arranged with respect to time, said equipment comprising:

- 30 first means for inputting the image sequence;
second means for acquiring a motion trajectory of an image contour of a target included within a region defined by an arbitrary spatial range and time range within the image sequence input by said first means,
35 as three-dimensional volume data drawn within a spatiotemporal space in which each of the frames is time-sequentially stacked;

- 1 third means for acquiring a plane histogram of
one of tangent planes tangent to the motion trajectory
and partial planes which may be included in the motion
trajectory; and
- 5 fourth means for measuring temporal features and
spatial features of the image from the plane histogram
which is acquired by said third means.

10

22. An equipment for extracting image
features from an image sequence in which frames
indicating images are time-sequentially arranged with
15 respect to time, said equipment comprising:
- first means for inputting the image sequence;
- second means for acquiring a motion trajectory of
an image contour of a target included within a region
defined by an arbitrary spatial range and time range
20 within the image sequence input by said first means,
as three-dimensional volume data drawn within a
spatiotemporal space in which each of the frames is
time-sequentially stacked;
- third means for acquiring a plane histogram of
25 tangent planes tangent to the motion trajectory;
- fourth means for estimating a velocity component
of the target which moves within the region from the
plane histogram acquired by said third means;
- fifth means for extracting a distribution of the
30 tangent planes corresponding to the image contour of
the target which moves at the velocity component
estimated by said fourth means, from the plane
histogram acquired by said third means; and
- sixth means for acquiring spatial features of the
35 image from the distribution of the tangent planes
extracted by said fifth means.

1 23. The equipment as claimed in claim 22,
wherein said fourth means includes:

seventh means for acquiring a histogram of
intersection lines of the tangent planes from the
5 plane histogram acquired by said third means; and
eighth means for acquiring, as image features, a
most dominant translational velocity component of the
target which moves within the defined region, from the
histogram of the intersection lines acquired by said
10 seventh means.

15 24. The equipment as claimed in claim 22,
wherein said fourth means includes:

seventh means for acquiring a histogram of
intersection lines of the tangent planes from the
plane histogram acquired by said third means; and
20 eighth means for detecting a plurality of peaks
from the histogram of the intersection lines acquired
by said seventh means;

ninth means for acquiring velocity components of
a plurality of motions within the region corresponding
25 to the plurality of peaks detected by said eighth
means; and

tenth means for judging whether or not each of
the velocity components can be represented by a
composite velocity of other velocity components, with
30 respect to the velocity components acquired by said
ninth means, and outputting an independent velocity
component which cannot be represented by the composite
velocity of the other velocity components.

1 25. The equipment as claimed in claim 22,
wherein said fifth means extracts a distribution of
tangent planes along tangent line directions to the
image contour of the target, and said sixth means
5 calculates feature values related to a directionality
of the image contour of the target from the
distribution of the tangent planes extracted by said
fifth means.

10

26. The equipment as claimed in claim 22,
wherein said fifth means extracts a distribution of
15 tangent planes in directions perpendicular to a
direction of the image contour of the target, and said
sixth means extracts features related to a spatial
arrangement of the image contour of the target.

20

27. An equipment for extracting image
features from an image sequence in which frames
25 indicating images are time-sequentially arranged with
respect to time, said equipment comprising:
first means for inputting the image sequence;
second means for acquiring a motion trajectory of
an image contour of a target included within a region
30 defined by an arbitrary spatial range and time range
within the image sequence input by said first means,
as three-dimensional volume data drawn within a
spatiotemporal space in which each of the frames is
time-sequentially stacked;
35 third means for acquiring a plane histogram of
tangent planes tangent to the motion trajectory;
fourth means for acquiring a histogram of

1 intersection lines of the tangent planes from the
plane histogram acquired by said third means;
fifth means for detecting a plurality of peaks
from the histogram of the intersection lines acquired
5 by said fourth means; and
sixth means for acquiring a plurality of velocity
components of motions within the region corresponding
to the plurality of peaks detected by said fifth
means.

10

28. The equipment as claimed in claim 27,
15 which further comprises:

seventh means for judging whether or not each of
the velocity components can be represented by a
composite velocity of other velocity components, with
respect to the plurality of velocity components
20 acquired by said fifth means; and

eighth means for outputting an independent
velocity component which cannot be represented by the
composite velocity of the other velocity components.

25

29. An equipment for extracting image
features from an image sequence in which frames
30 indicating images are time-sequentially arranged with
respect to time, said equipment comprising:

first means for inputting the image sequence;

second means for acquiring a motion trajectory of
an image contour of a target included within a region
35 defined by an arbitrary spatial range and time range
within the image sequence input by said first means,
as three-dimensional volume data drawn within a

1 spatiotemporal space in which each of the frames is
time-sequentially stacked;

third means for acquiring a plane histogram of
one of tangent planes tangent to the motion trajectory
5 and partial planes which may be included in the motion
trajectory;

fourth means for acquiring a normal flow
histogram of normal flows of the image from the plane
histogram acquired by said third means; and

10 fifth means for acquiring temporal features of
the image from the normal flow histogram acquired by
said fourth means.

15

30. The equipment as claimed in claim 29,
wherein said fourth means acquires a normal flow
histogram having direction and velocity of the normal
20 flows as variables, and said fifth means calculates
spreading of the normal flow histogram as feature
values representing motion uniformity of the image.

25

31. The equipment as claimed in claim 29,
wherein said fourth means acquires a normal flow
histogram having velocity of the normal flows as a
30 variable, and said fifth means calculates a ratio of
totalled frequency value corresponding to normal flows
having specific velocities with respect to a totalled
frequency value as a whole as feature values
representing the motion of the image.

35

1 32. An equipment for extracting image
features from an image sequence in which frames
indicating images are time-sequentially arranged with
respect to time, said equipment comprising:
5 first means for inputting the image sequence;
 second means for acquiring a motion trajectory of
an image contour of a target included within a region
defined by an arbitrary spatial range and time range
within the image sequence input by said first means,
10 as three-dimensional volume data drawn within a
spatiotemporal space in which each of the frames is
time-sequentially stacked;
 third means for detecting tangent planes tangent
to the motion trajectory;
15 fourth means for extracting, as an image, a
distribution of the motion trajectory existing on the
tangent planes detected by said third means; and
 fifth means for tracking a motion trajectory on
the image extracted by said fourth means and detecting
20 an occlusion of the target.

25 33. The equipment as claimed in claim 32,
wherein said fifth means includes:
 sixth means for measuring intermittence along a
moving direction of the motion trajectory; and
 seventh means for detecting the occlusion of the
30 target based on the intermittence measured by said
sixth means.

35 34. The equipment as claimed in claim 32,
wherein said fifth means includes:

1 sixth means for measuring statistics of a run
length along a moving direction of the motion
trajectory; and
 seventh means for detecting a degree of the
5 occlusion of the target from the statistics of the run
length measured by said sixth means.

10

 35. The equipment as claimed in claim 32,
wherein said third means detects the tangent planes in
a form of a histogram of the tangent planes which are
represented as a distribution of votes accumulated in
15 a plane parameter space obtained by use of a three-
dimensional Hough transform.

20

 36. The equipment as claimed in claim 32,
wherein said third means detects tangent planes
corresponding estimated velocity components.

25

 37. The equipment as claimed in any of
claims 20, 21, 22, 27, 29 and 32, wherein the three-
30 dimensional volume data is obtained by forming
difference images among the frames in time sequence,
and stacking the formed difference images.

35

 38. The equipment as claimed in any of

1 claims 21, 22, 23 and 29, wherein the plane histogram
is obtained as votes accumulated in a plane parameter
space obtained by use of a three-dimensional Hough
transform.

5

39. A computer-readable recording medium
10 recorded with a program for causing a computer to
extract image features from an image sequence in which
frames indicating images are time-sequentially
arranged with respect to time, said program
comprising:

15 a first code for causing the computer to input
the image sequence;

a second code for causing the computer to acquire
a motion trajectory of an image contour of a target
included within a region defined by an arbitrary
20 spatial range and time range within the image sequence
input by said first code, as three-dimensional volume
data drawn within a spatiotemporal space in which each
of the frames is time-sequentially stacked; and

a third code for causing the computer to measure
25 temporal features and spatial features of the image
from the motion trajectory which is acquired as the
three-dimensional volume data by said second code.

30

40. A computer-readable recording medium
recorded with a program for causing a computer to
extract image features from an image sequence in which
35 frames indicating images are time-sequentially
arranged with respect to time, said program
comprising:

1 a first code for causing the computer to input
the image sequence;
a second code for causing the computer to acquire
a motion trajectory of an image contour of a target
5 included within a region defined by an arbitrary
spatial range and time range within the image sequence
input by said first code, as three-dimensional volume
data drawn within a spatiotemporal space in which each
of the frames is time-sequentially stacked;
10 a third code for causing the computer to acquire
a plane histogram of one of tangent planes tangent to
the motion trajectory and partial planes which may be
included in the motion trajectory; and
a fourth code for causing the computer to measure
15 temporal features and spatial features of the image
from the plane histogram which is acquired by said
third code.

20

41. A computer-readable recording medium
recorded with a program for causing a computer to
extract image features from an image sequence in which
25 frames indicating images are time-sequentially
arranged with respect to time, said program
comprising:

a first code for causing the computer to input
the image sequence;
30 a second code for causing the computer to acquire
a motion trajectory of an image contour of a target
included within a region defined by an arbitrary
spatial range and time range within the image sequence
input by said first code, as three-dimensional volume
35 data drawn within a spatiotemporal space in which each
of the frames is time-sequentially stacked;
a third code for causing the computer to acquire

1 a plane histogram of tangent planes tangent to the
motion trajectory;

a fourth code for causing the computer to
estimate a velocity component of the target which
5 moves within the region from the plane histogram
acquired by said third code;

a fifth code for causing the computer to extract
a distribution of the tangent planes corresponding to
the image contour of the target which moves at the
10 velocity component estimated by said fourth code, from
the plane histogram acquired by said third code; and

a sixth code for causing the computer to acquire
spatial features of the image from the distribution of
the tangent planes extracted by said fifth code.

15

42. The computer-readable recording medium
20 as claimed in claim 41, wherein said fourth code
includes:

seventh code for causing the computer to acquire
a histogram of intersection lines of the tangent
planes from the plane histogram acquired by said third
25 code; and

an eighth code for causing the computer to
acquire, as image features, a most dominant
translational velocity component of the target which
moves within the defined region, from the histogram of
30 the intersection lines acquired by said seventh code.

35 43. The computer-readable recording medium
as claimed in claim 41, wherein said fourth code
includes:

- 1 a seventh code for causing the computer to
acquire a histogram of intersection lines of the
tangent planes from the plane histogram acquired by
said third code; and
- 5 an eighth code for causing the computer to detect
a plurality of peaks from the histogram of the
intersection lines acquired by said seventh code;
- a ninth code for causing the computer to acquire
velocity components of a plurality of motions within
- 10 the region corresponding to the plurality of peaks
detected by said eighth code; and
- a tenth code for causing the computer to judge
whether or not each of the velocity components can be
represented by a composite velocity of other velocity
- 15 components, with respect to the velocity components
acquired by said ninth code, and output an independent
velocity component which cannot be represented by the
composite velocity of the other velocity components.

20

44. The computer-readable recording medium
as claimed in claim 41, wherein said fifth code causes
- 25 the computer to extract a distribution of tangent
planes along tangent line directions to the image
contour of the target, and said sixth code causes the
computer to calculate feature values related to a
directionality of the image contour of the target from
- 30 the distribution of the tangent planes extracted by
said fifth code.

35

45. The computer-readable recording medium
as claimed in claim 41, wherein said fifth code causes

1 the computer to extract a distribution of tangent
planes in directions perpendicular to a direction of
the image contour of the target, and said sixth code
causes the computer to extract features related to a
5 spatial arrangement of the image contour of the
target.

10

46. A computer-readable recording medium
recorded with a program for causing a computer to
extract image features from an image sequence in which
frames indicating images are time-sequentially
15 arranged with respect to time, said program
comprising:

a first code for causing the computer to input
the image sequence;

a second code for causing the computer to acquire
20 a motion trajectory of an image contour of a target
included within a region defined by an arbitrary
spatial range and time range within the image sequence
input by said first code, as three-dimensional volume
data drawn within a spatiotemporal space in which each
25 of the frames is time-sequentially stacked;

a third code for causing the computer to acquire
a plane histogram of tangent planes tangent to the
motion trajectory;

a fourth code for causing the computer to acquire
30 a histogram of intersection lines of the tangent
planes from the plane histogram acquired by said third
code;

a fifth code for causing the computer to detect a
plurality of peaks from the histogram of the
35 intersection lines acquired by said fourth code; and

a sixth code for causing the computer to acquire
a plurality of velocity components of motions within

1 the region corresponding to the plurality of peaks
detected by said fifth code.

5

47. The computer-readable recording medium
as claimed in claim 46, wherein said program further
comprises:

10 a seventh code for causing the computer to judge
whether or not each of the velocity components can be
represented by a composite velocity of other velocity
components, with respect to the plurality of velocity
components acquired by said fifth code; and

15 an eighth code for causing the computer to output
an independent velocity component which cannot be
represented by the composite velocity of the other
velocity components.

20

48. A computer-readable recording medium
recorded with a program for causing a computer to
25 extract image features from an image sequence in which
frames indicating images are time-sequentially
arranged with respect to time, said program
comprising:

a first code for causing the computer to input
30 the image sequence;

a second code for causing the computer to acquire
a motion trajectory of an image contour of a target
included within a region defined by an arbitrary
spatial range and time range within the image sequence
35 input by said first code, as three-dimensional volume
data drawn within a spatiotemporal space in which each
of the frames is time-sequentially stacked;

1 a third code for causing the computer to acquire
a plane histogram of one of tangent planes tangent to
the motion trajectory and partial planes which may be
included in the motion trajectory;

5 a fourth code for causing the computer to acquire
a normal flow histogram of normal flows of the image
from the plane histogram acquired by said third code;
and

10 a fifth code for causing the computer to acquire
temporal features of the image from the normal flow
histogram acquired by said fourth code.

15

49. The computer-readable recording medium
as claimed in claim 48, wherein said fourth code
causes the computer to acquire a normal flow histogram
having direction and velocity of the normal flows as
20 variables, and said fifth code causes the computer to
calculate spreading of the normal flow histogram as
feature values representing motion uniformity of the
image.

25

50. The computer-readable recording medium
as claimed in claim 48, wherein said fourth code
30 causes the computer to acquire a normal flow histogram
having velocity of the normal flows as a variable, and
said fifth code causes the computer to calculate a
ratio of totalled frequency value corresponding to
normal flows having specific velocities with respect
35 to a totalled frequency value as a whole as feature
values representing the motion of the image.

1 51. A computer-readable recording medium
recorded with a program for causing a computer to
extract image features from an image sequence in which
frames indicating images are time-sequentially
5 arranged with respect to time, said program
comprising:

 a first code for causing the computer to input
the image sequence;

 a second code for causing the computer to acquire
10 a motion trajectory of an image contour of a target
included within a region defined by an arbitrary
spatial range and time range within the image sequence
input by said first code, as three-dimensional volume
data drawn within a spatiotemporal space in which each
15 of the frames is time-sequentially stacked;

 a third code for causing the computer to detect
tangent planes tangent to the motion trajectory;

 a fourth code for causing the computer to
extract, as an image, a distribution of the motion
20 trajectory existing on the tangent planes detected by
said third code; and

 a fifth code for causing the computer to track a
motion trajectory on the image extracted by said
fourth code and detecting an occlusion of the target.
25

 52. The computer-readable recording medium
30 as claimed in claim 51, wherein said fifth code
includes:

 a sixth code for causing the computer to measure
intermittence along a moving direction of the motion
trajectory; and

35 a seventh code for causing the computer to detect
the occlusion of the target based on the intermittence
measured by said sixth code.

1 53. The computer-readable recording medium
as claimed in claim 51, wherein said fifth code
includes:

5 a sixth code for causing the computer to measure
statistics of a run length along a moving direction of
the motion trajectory; and

 a seventh code for causing the computer to detect
a degree of the occlusion of the target from the
statistics of the run length measured by said sixth
10 code.

15 54. The computer-readable recording medium
as claimed in claim 51, wherein said third code causes
the computer to detect the tangent planes in a form of
a histogram of the tangent planes which are
represented as a distribution of votes accumulated in
20 a plane parameter space obtained by use of a three-
dimensional Hough transform.

25 55. The computer-readable recording medium
as claimed in claim 51, wherein said third code causes
the computer to detect tangent planes corresponding
estimated velocity components.

30

 56. The computer-readable recording medium
35 as claimed in any of claims 39, 40, 41, 46, 48 and 51,
wherein the three-dimensional volume data is obtained
by forming difference images among the frames in time

1 sequence, and stacking the formed difference images.

5

57. The computer-readable recording medium
as claimed in any of claims 40, 41, 42, 46 and 48,
wherein the plane histogram is obtained as votes
accumulated in a plane parameter space obtained by use
10 of a three-dimensional Hough transform.

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1 ABSTRACT OF THE DISCLOSURE

A method and an equipment extracts image features from an image sequence in which frames indicating images are time-sequentially arranged with respect to time. The equipment includes a unit for inputting the image sequence, a unit for acquiring a motion trajectory of an image contour of a target included within a region defined by an arbitrary spatial range and time range within the input image sequence, as three-dimensional volume data drawn within a spatiotemporal space in which each of the frames is time-sequentially stacked, a unit for acquiring a plane histogram of one of tangent planes tangent to the motion trajectory and partial planes which may be included in the motion trajectory, and a unit for measuring temporal features and spatial features of the image from the acquired plane histogram. The three-dimensional volume data is obtained by forming difference images among the frames arranged in the time sequence and stacking the formed difference images. The plane histogram is obtained as votes accumulated in a plane parameter space obtained by use of the Hough transform.

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35

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DECLARATION AND POWER OF ATTORNEY - ORIGINAL APPLICATION			ATTORNEY'S DOCKET NO. <div style="font-size: 1.5em; margin-top: 5px;">10746/1</div>																												
<p>As a below named inventor, I hereby declare that: My residence, post office address and citizenship are as stated below next to my name, I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled <u>METHOD AND EQUIPMENT</u> <u>FOR EXTRACTING IMAGE FEATURES FROM IMAGE SEQUENCE</u></p> <hr/> <p>the specification of which (check one) <u> X </u> is attached hereto. _____ was filed on _____ as Application Serial No. _____ and was amended on _____ (if applicable).</p> <p>I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.</p> <p>I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).</p> <p>I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:</p> <p style="text-align: center;"><u>PRIOR FOREIGN APPLICATION(S)</u></p> <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <thead> <tr> <th style="width: 25%;">COUNTRY</th> <th style="width: 25%;">APPLICATION NUMBER</th> <th style="width: 20%;">DATE OF FILING (day, month, year)</th> <th style="width: 20%;">DATE OF ISSUE (day, month, year)</th> <th style="width: 10%;">PRIORITY CLAIMED UNDER 35 USC 119</th> </tr> </thead> <tbody> <tr> <td>as per attached</td> <td></td> <td></td> <td></td> <td><input type="checkbox"/> YES <input type="checkbox"/> NO</td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td><input type="checkbox"/> YES <input type="checkbox"/> NO</td> </tr> </tbody> </table> <p>I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:</p> <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <thead> <tr> <th style="width: 25%;">APPLICATION NO.</th> <th style="width: 40%;">FILING DATE (day, month, year)</th> <th style="width: 35%;">STATUS (i.e. Patented, Pending, Abandoned)</th> </tr> </thead> <tbody> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> </tbody> </table> <p>POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (List name and registration number)</p> <p style="margin-left: 40px;">Edward W. Greason, Esq. Reg. No. 18,918</p>					COUNTRY	APPLICATION NUMBER	DATE OF FILING (day, month, year)	DATE OF ISSUE (day, month, year)	PRIORITY CLAIMED UNDER 35 USC 119	as per attached				<input type="checkbox"/> YES <input type="checkbox"/> NO					<input type="checkbox"/> YES <input type="checkbox"/> NO	APPLICATION NO.	FILING DATE (day, month, year)	STATUS (i.e. Patented, Pending, Abandoned)									
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as per attached				<input type="checkbox"/> YES <input type="checkbox"/> NO																											
				<input type="checkbox"/> YES <input type="checkbox"/> NO																											
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	POST OFFICE ADDRESS	POST OFFICE ADDRESS	CITY	STATE & ZIP CODE/COUNTRY
<p>I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.</p>				
SIGNATURE OF INVENTOR 201 <i>Kazuhiro Otsuka</i>		SIGNATURE OF INVENTOR 202 <i>Tsutomu Horikoshi</i>		SIGNATURE OF INVENTOR 203 <i>Satoshi Suzuki</i>
DATE September 21, 1998		DATE September 21, 1998		DATE September 21, 1998
SIGNATURE OF INVENTOR 204		SIGNATURE OF INVENTOR 205		SIGNATURE OF INVENTOR 206
DATE		DATE		DATE

ATTACHMENT TO DECLARATION AND POWER OF ATTORNEY

PRIOR FOREIGN APPLICATIONS AS FOLLOWS:

<u>COUNTRY</u>	<u>APPLICATION NUMBER</u>	<u>DATE OF FILING</u> (Day/Month/Year)	<u>PRIORITY CLAIMED</u>
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Japan	Patent Application No.9-270263	03/10/97	YES
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Japan	Patent Application No.10-49091	02/03/98	YES
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Japan	Patent Application No.10-49092	02/03/98	YES
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Japan	Patent Application No.10-111731	22/04/98	YES
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Japan	Patent Application No.10-111732	22/04/98	YES
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FIG. 1

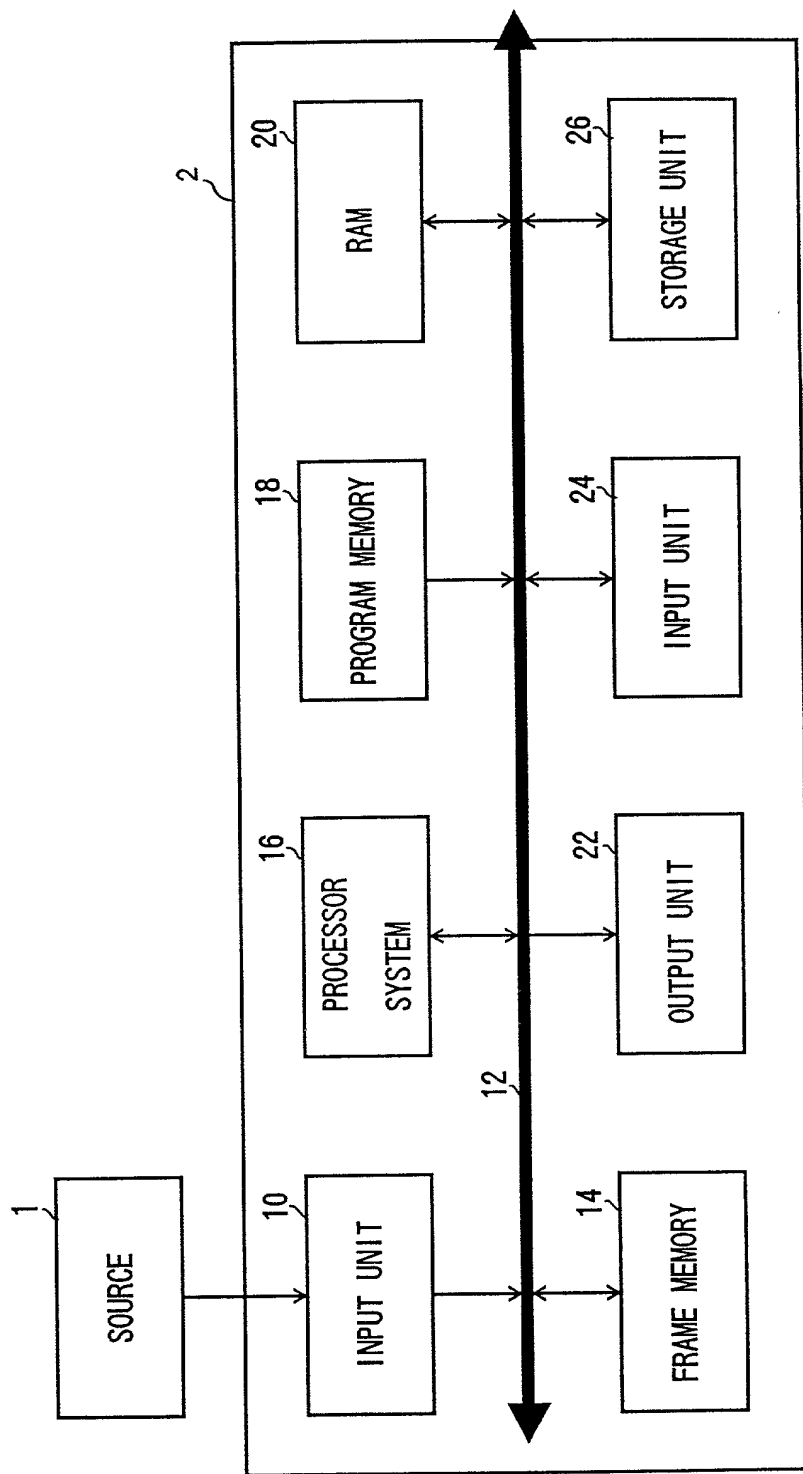


FIG. 2

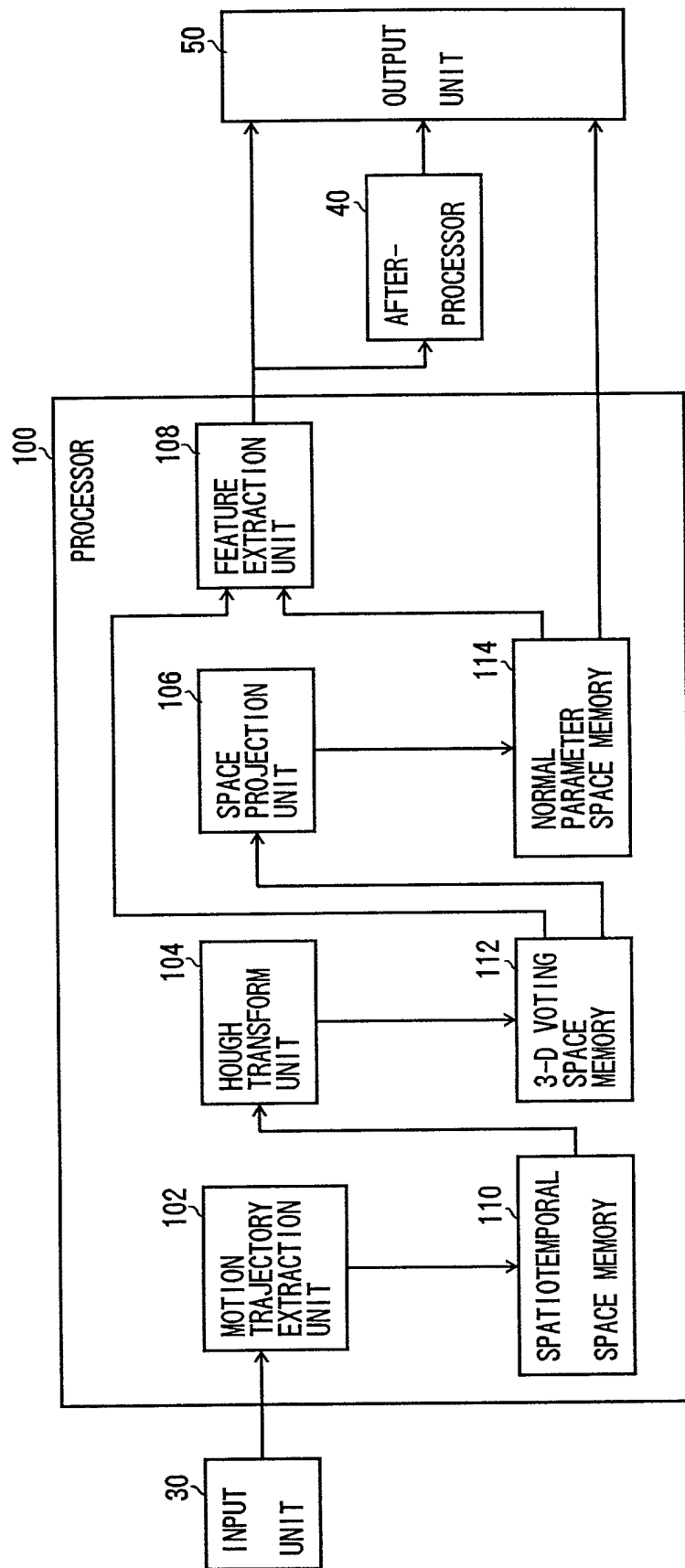


FIG. 3

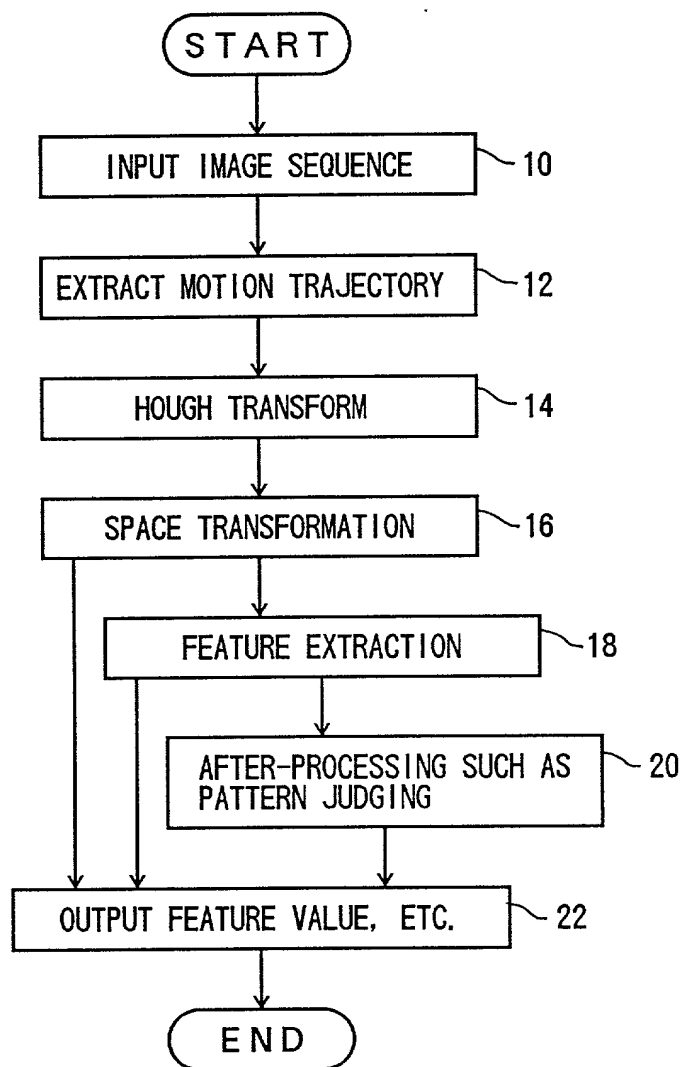


FIG. 4

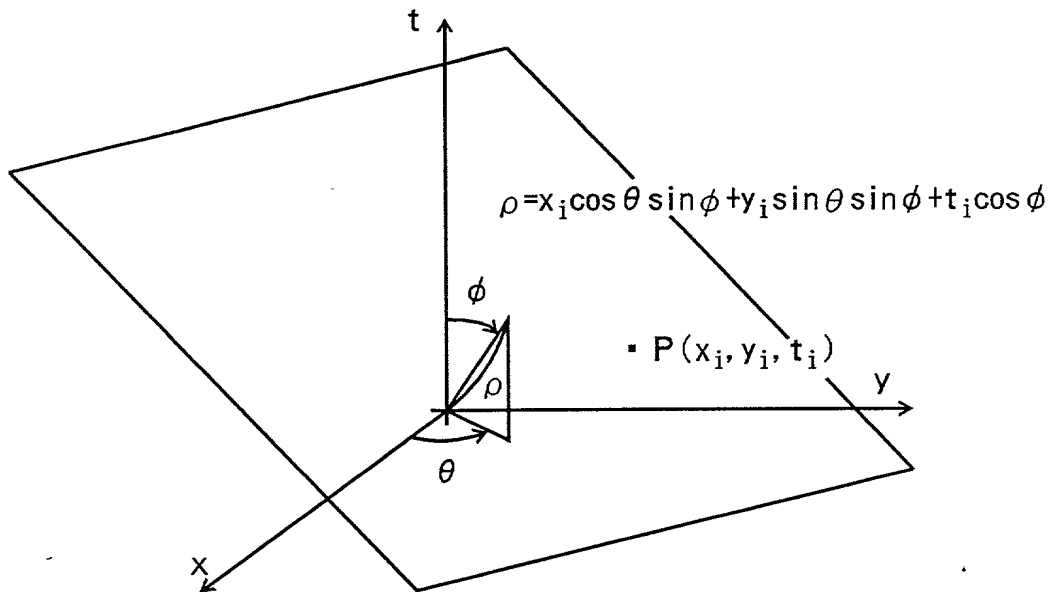


FIG.5

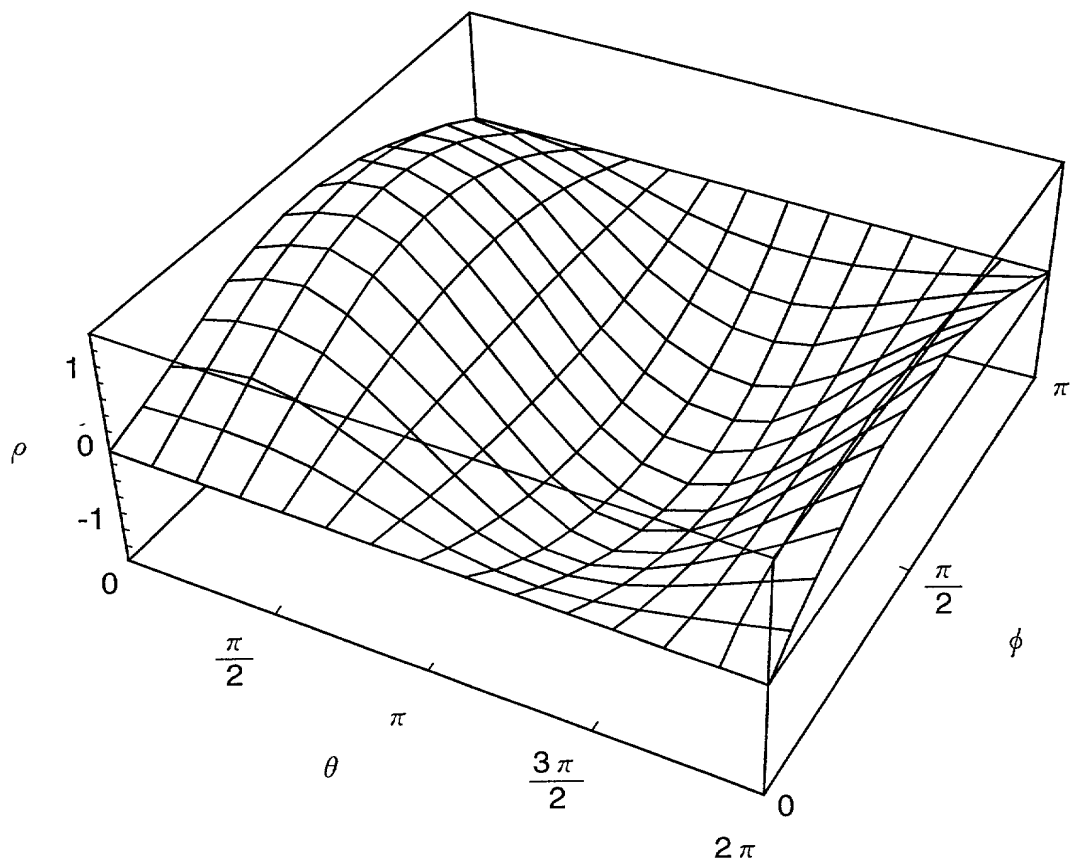


FIG. 6

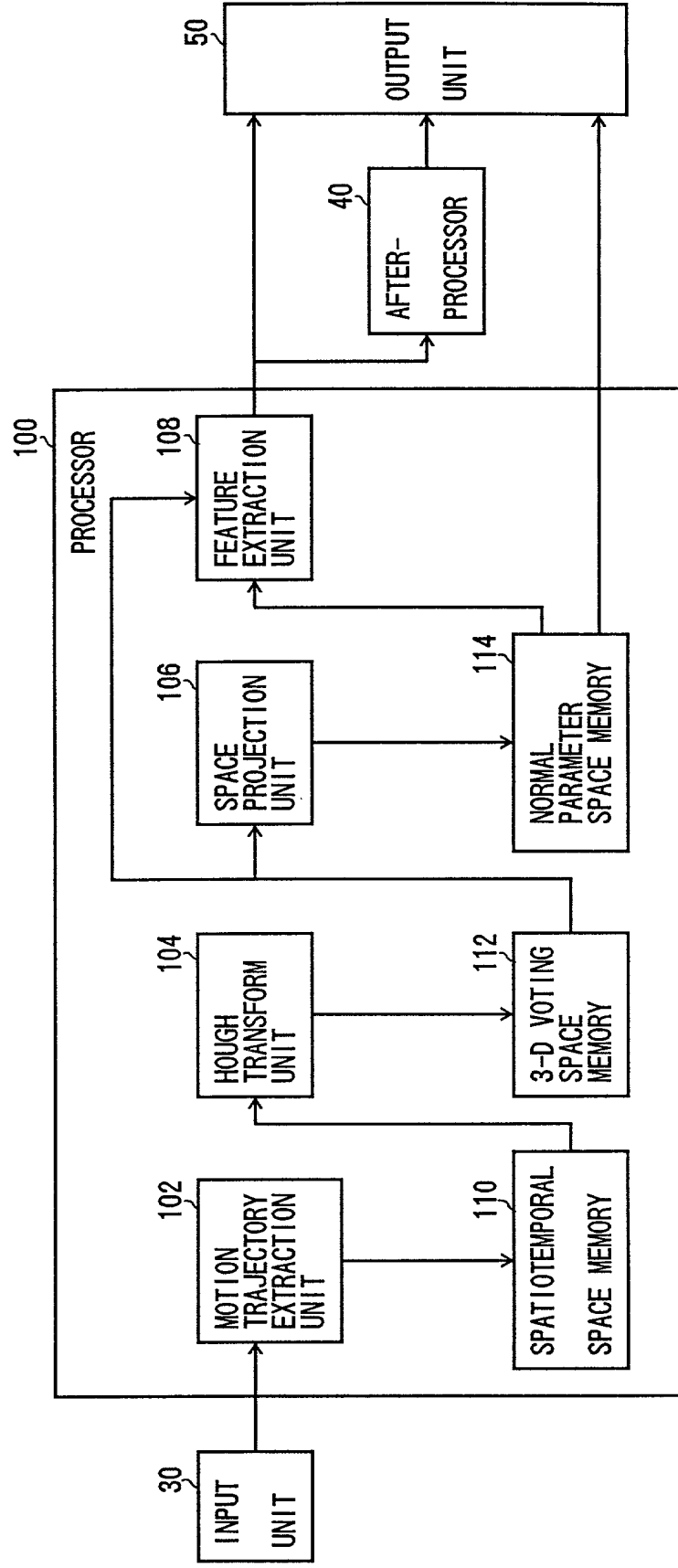


FIG. 7

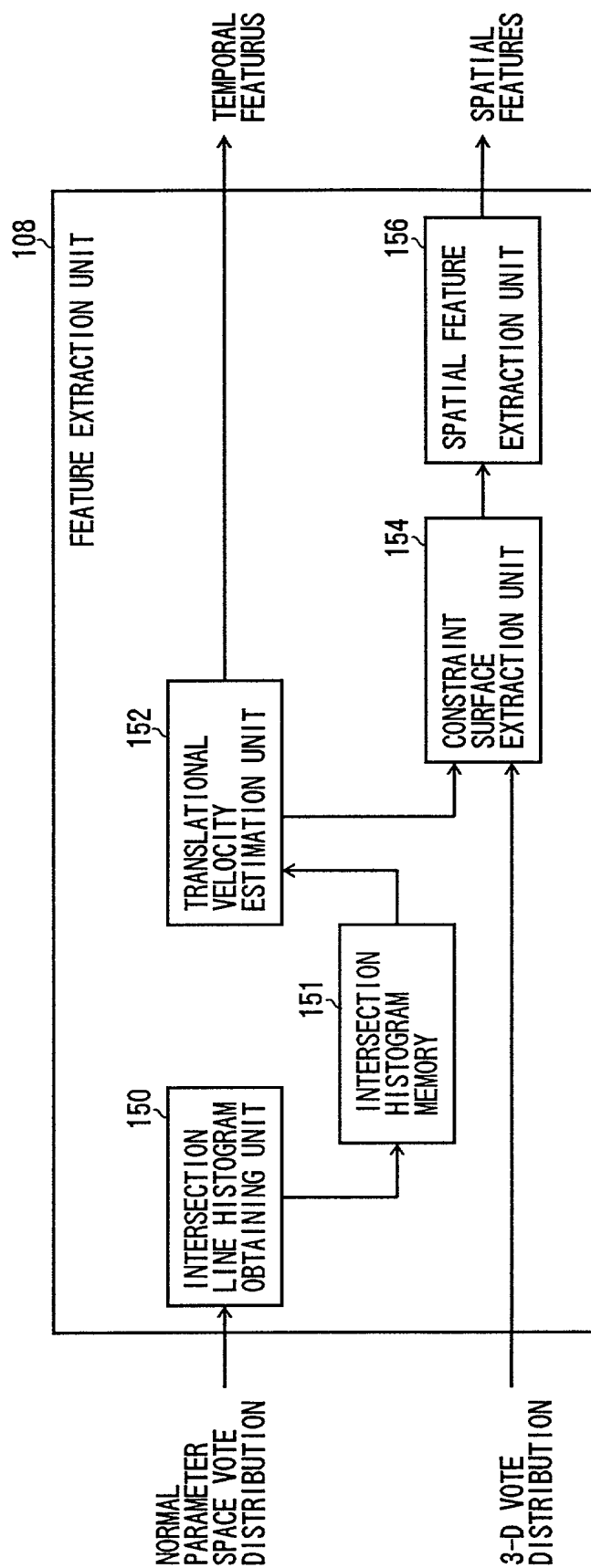


FIG.8

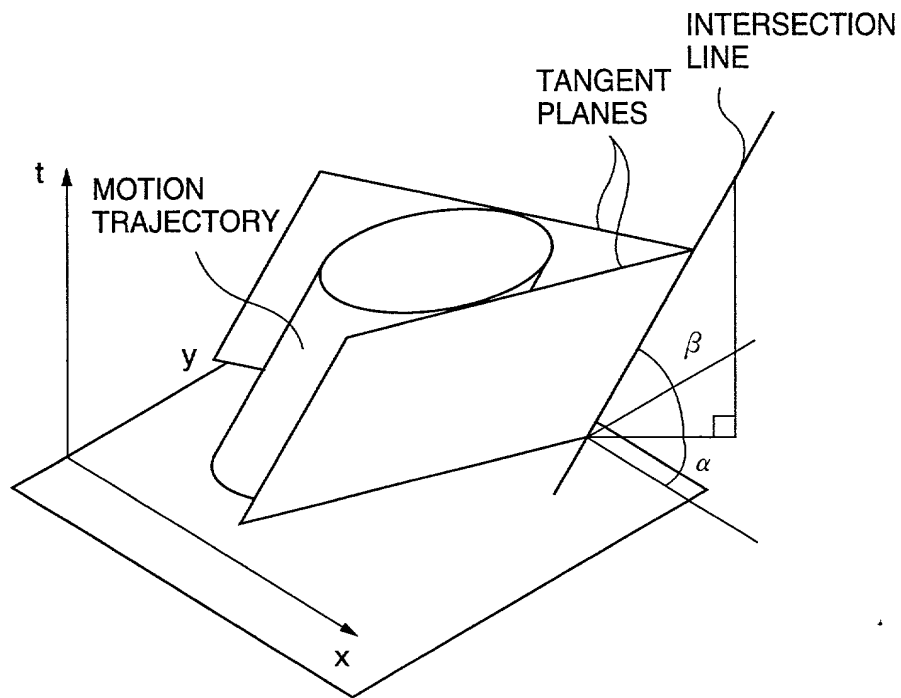


FIG. 9

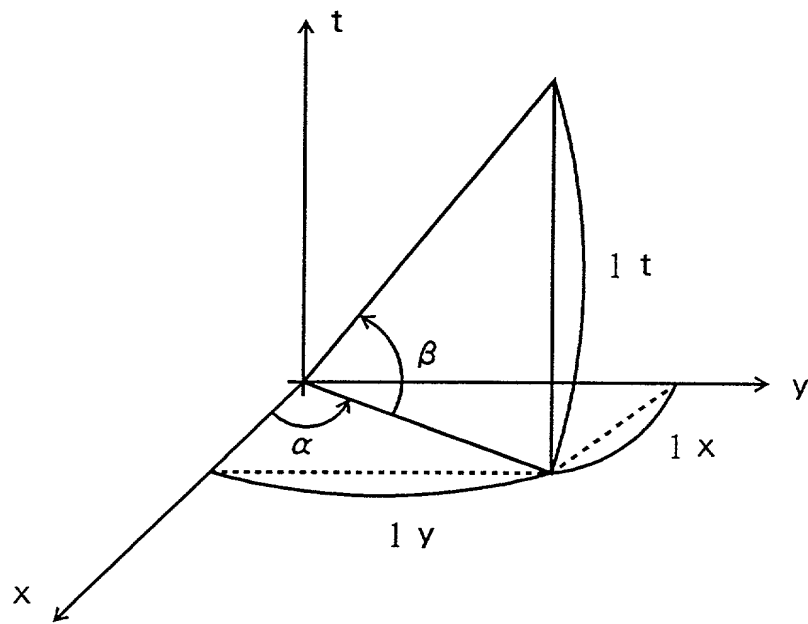


FIG.10

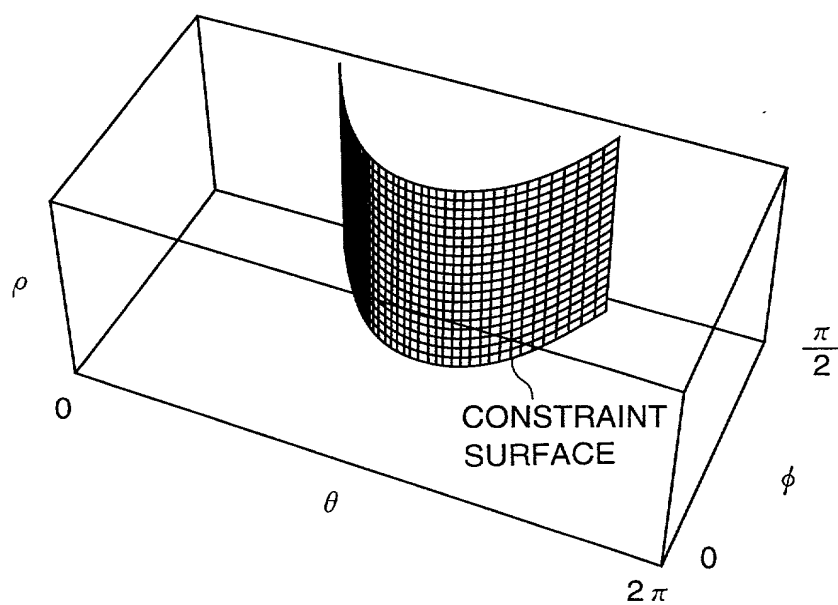


FIG. 11

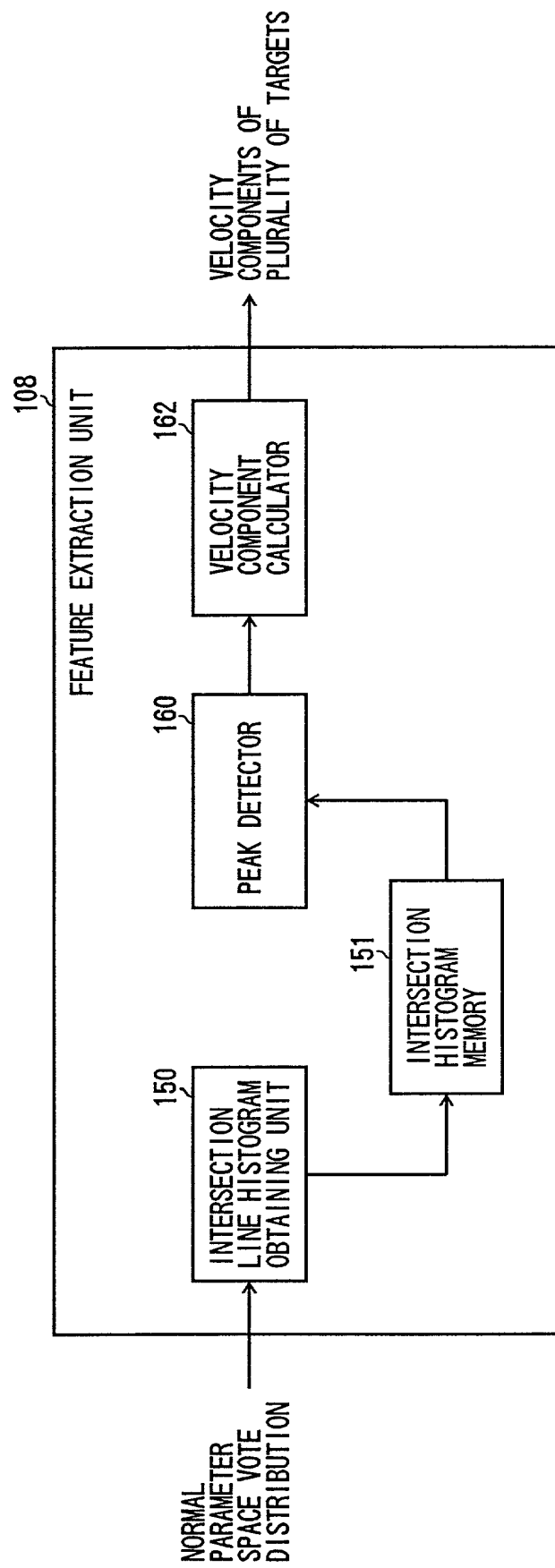


FIG. 12

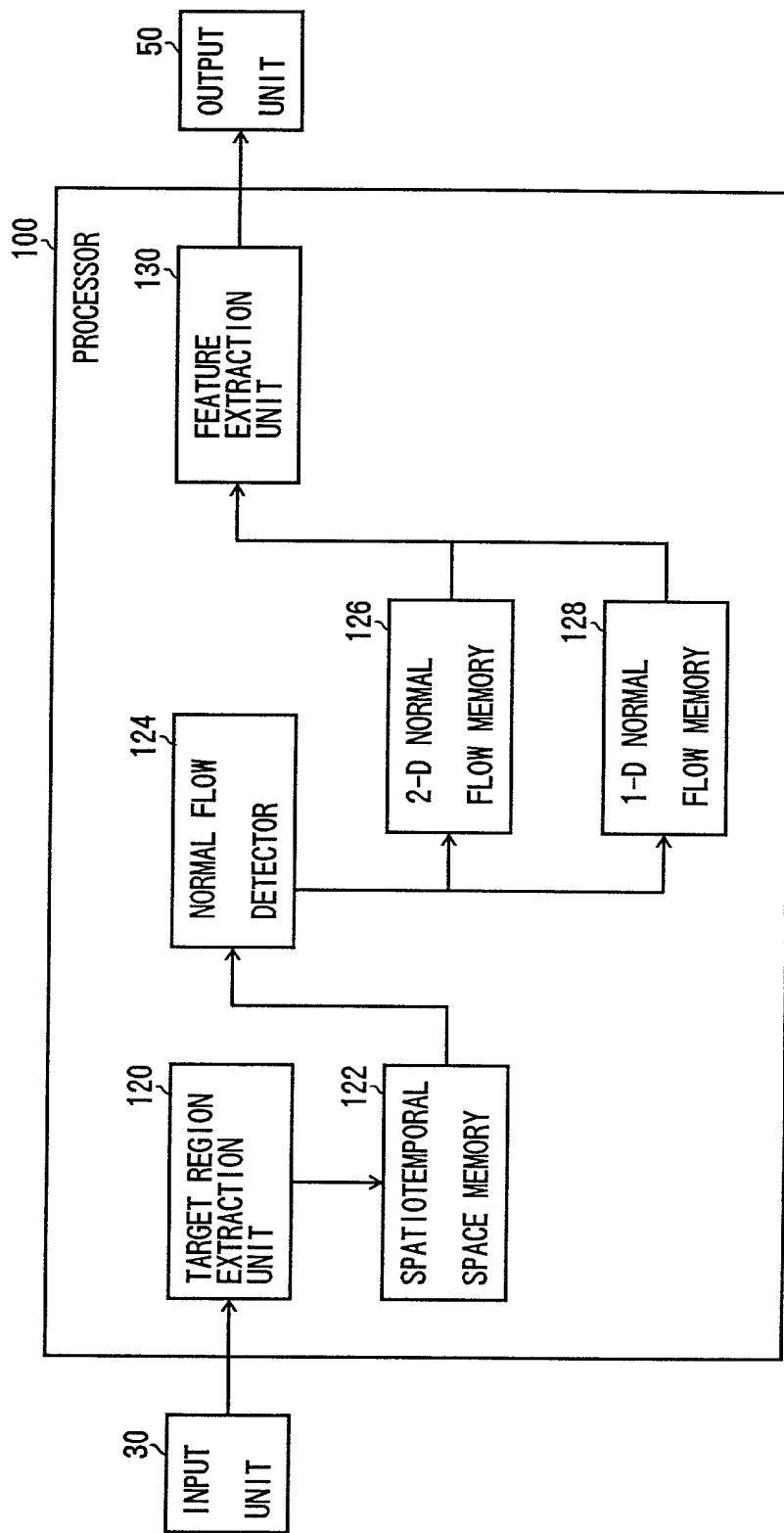


FIG. 13

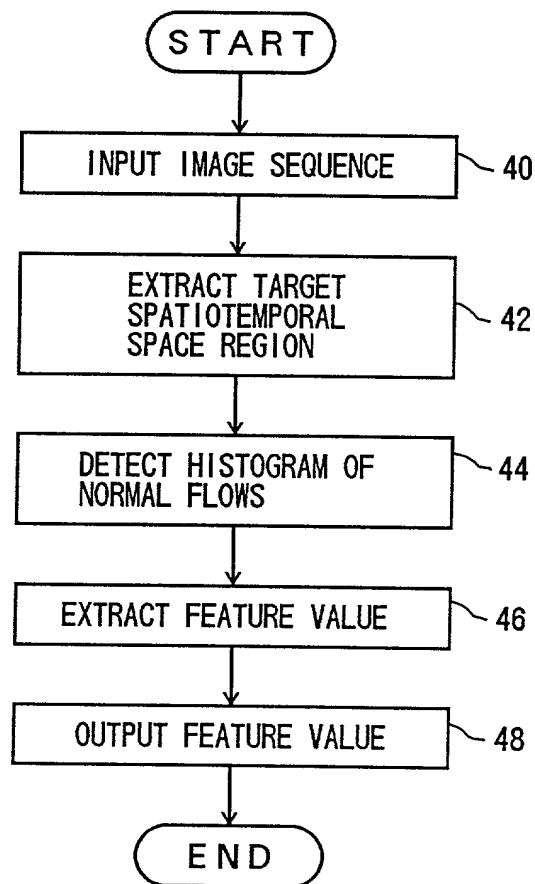


FIG. 14

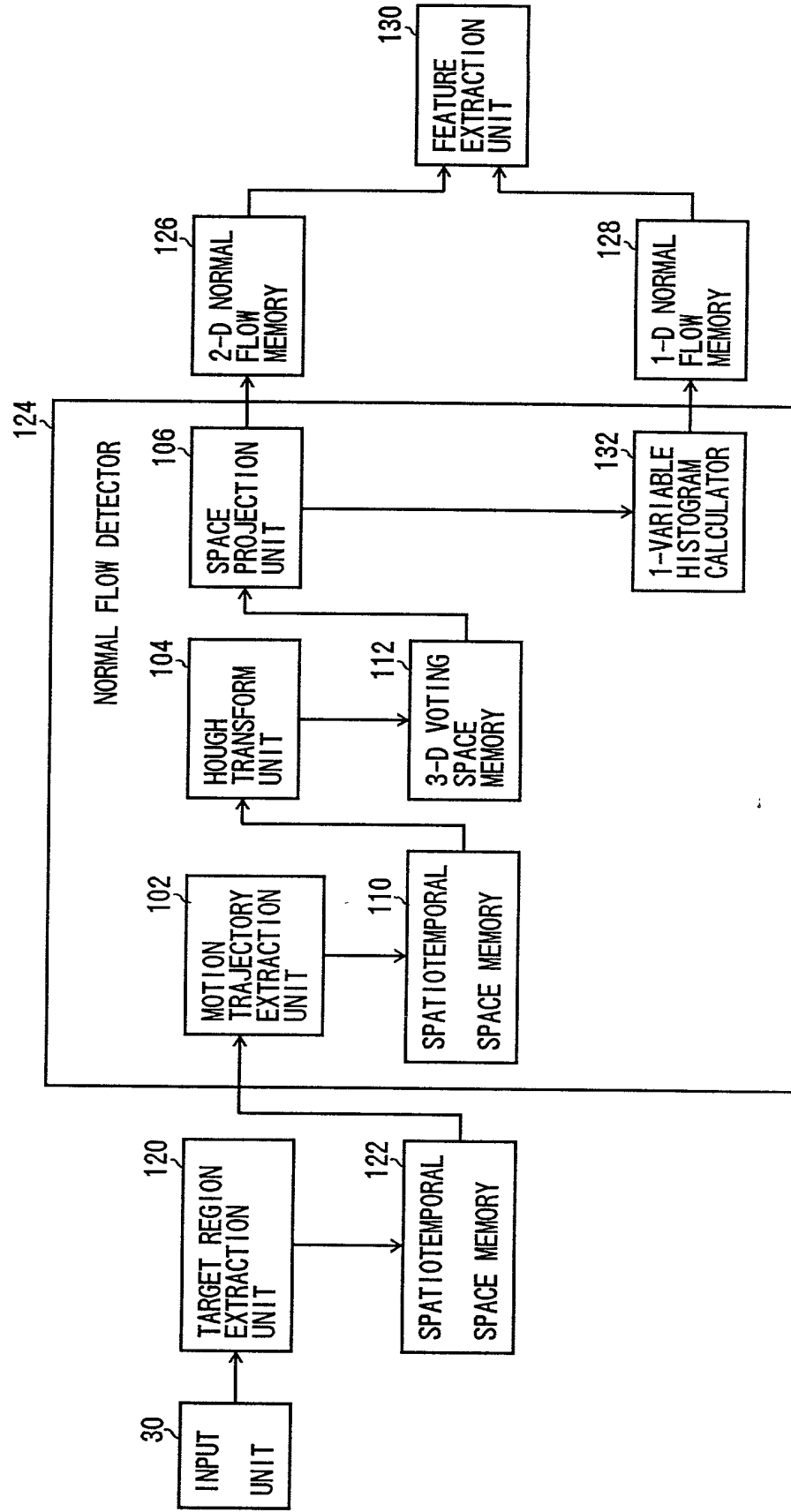


FIG. 15

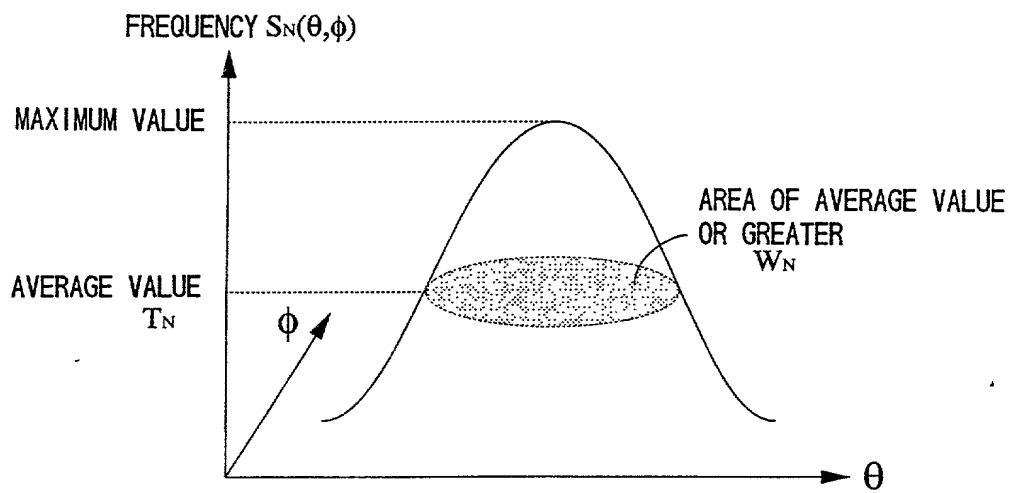


FIG. 16

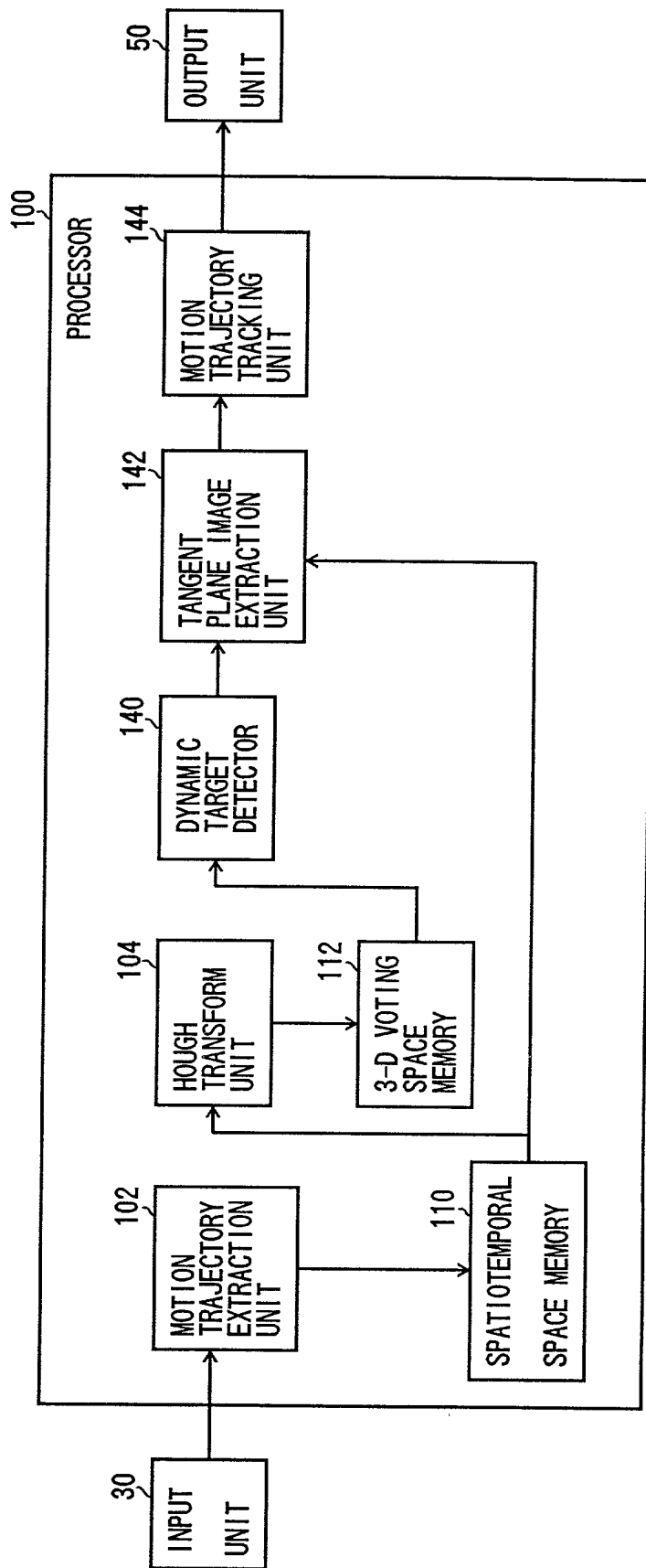


FIG. 17

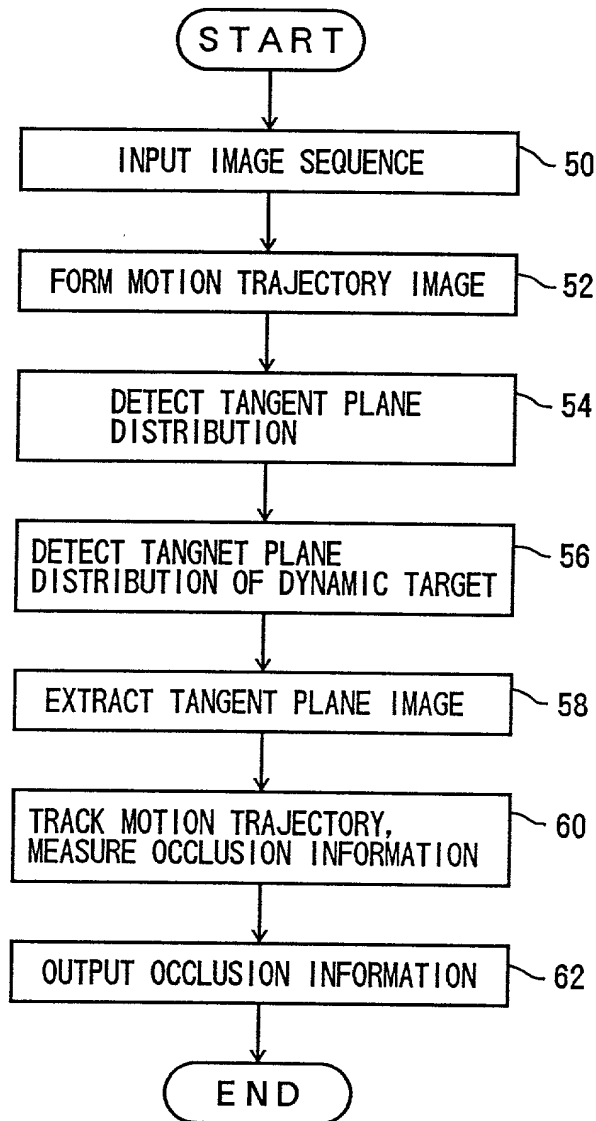


FIG. 18

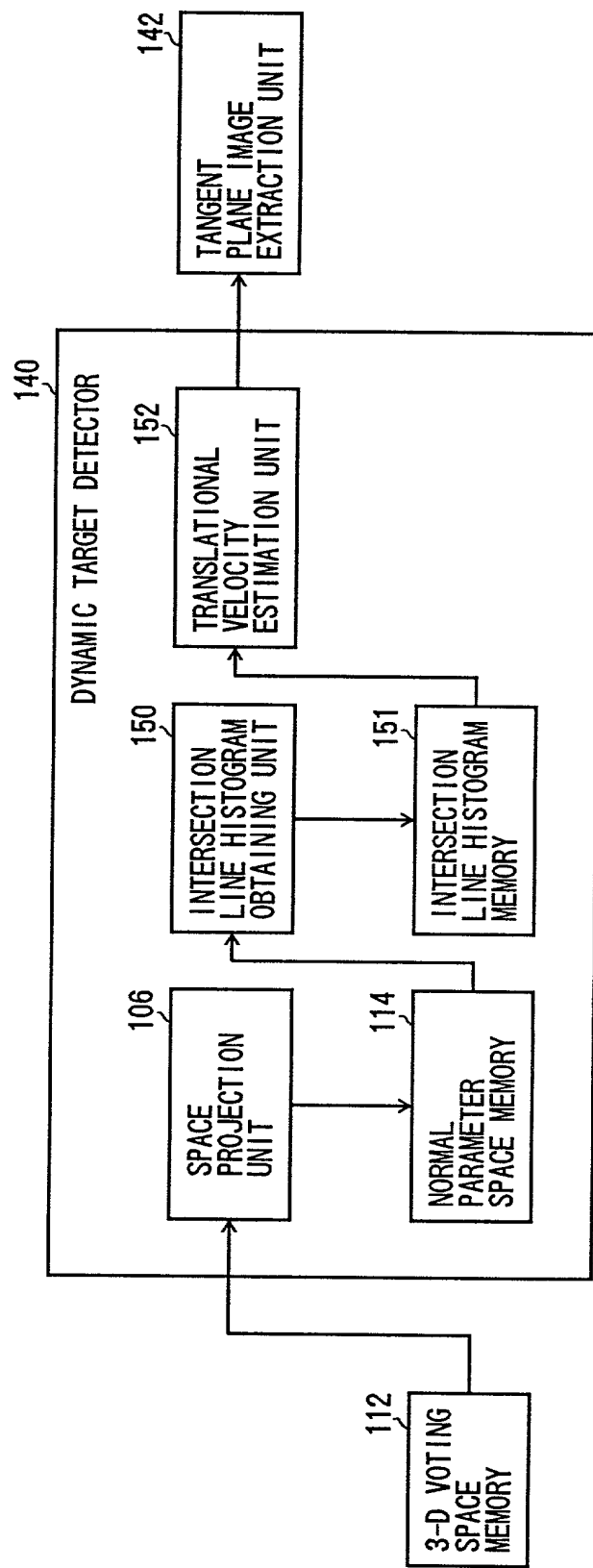


FIG. 20A

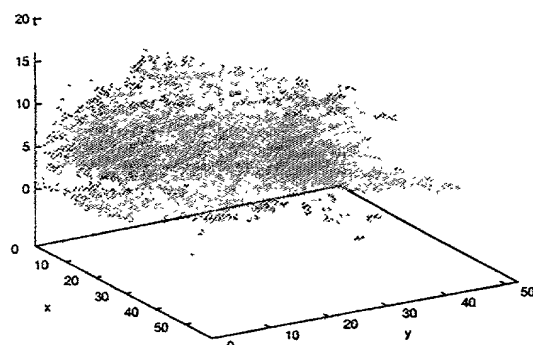


FIG. 20B

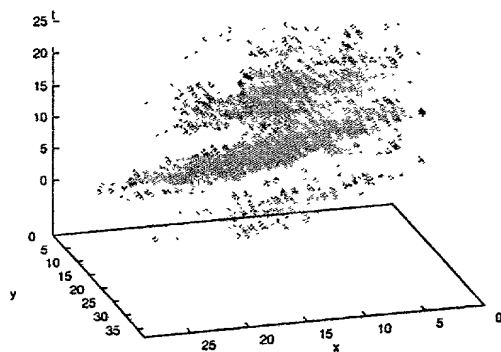
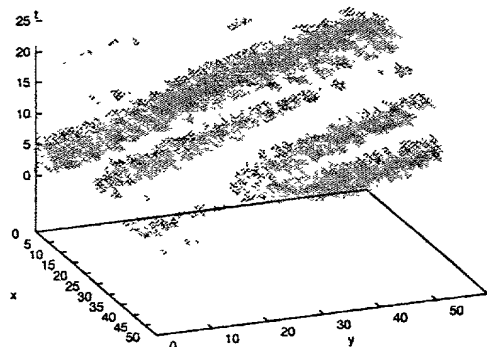


FIG. 20C



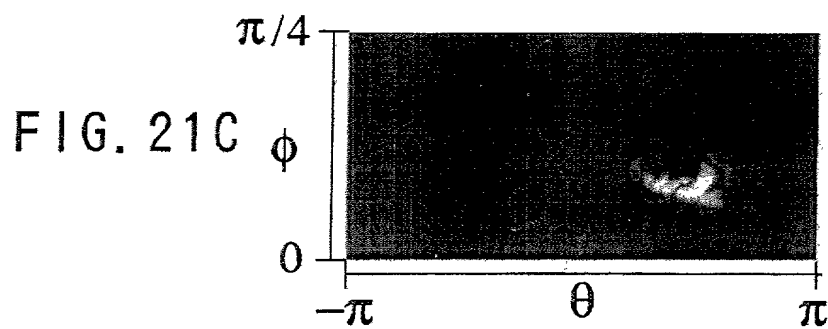
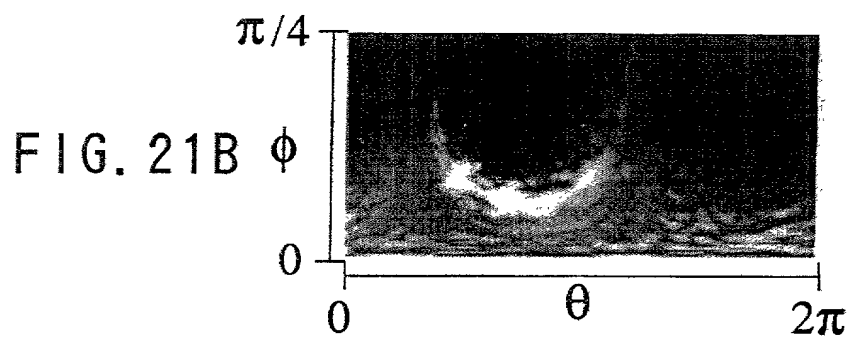
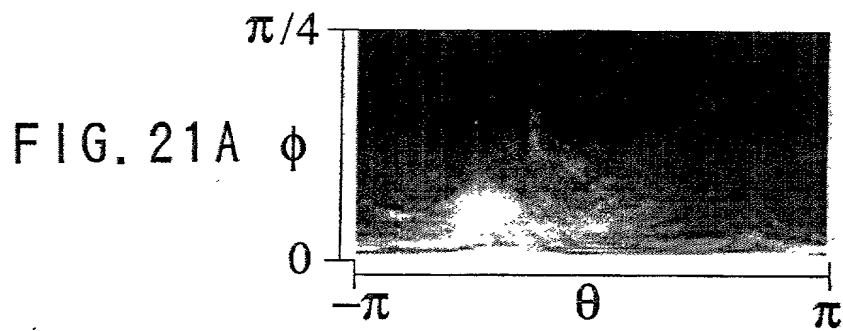
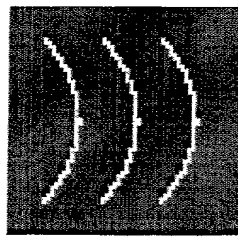


FIG. 22

	VELOCITY [pixel/frame]	DIRECTION [degree]
(a)	6.31	94
(b)	4.17	250
(c)	5.14	316

FIG. 23



Velocity :
1[pixel/frame]

FIG. 24

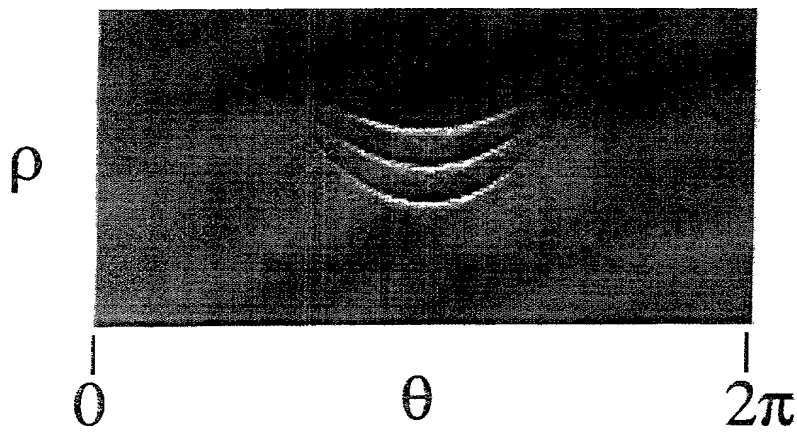


FIG. 25

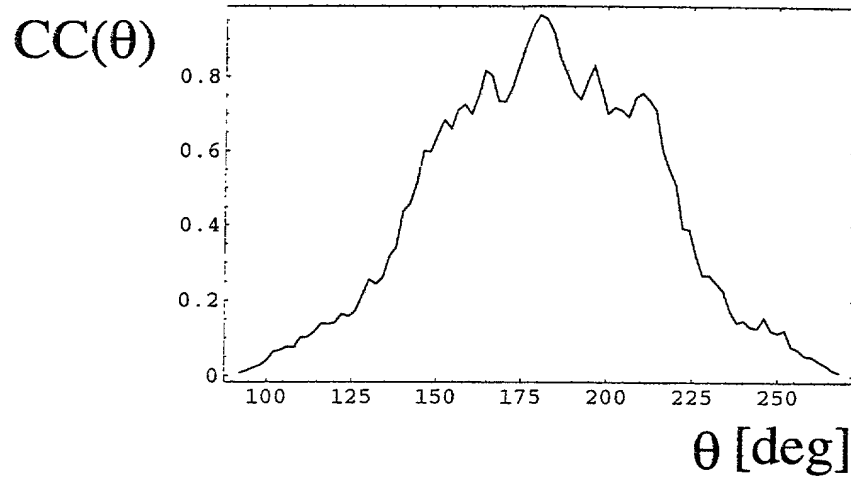


FIG. 26

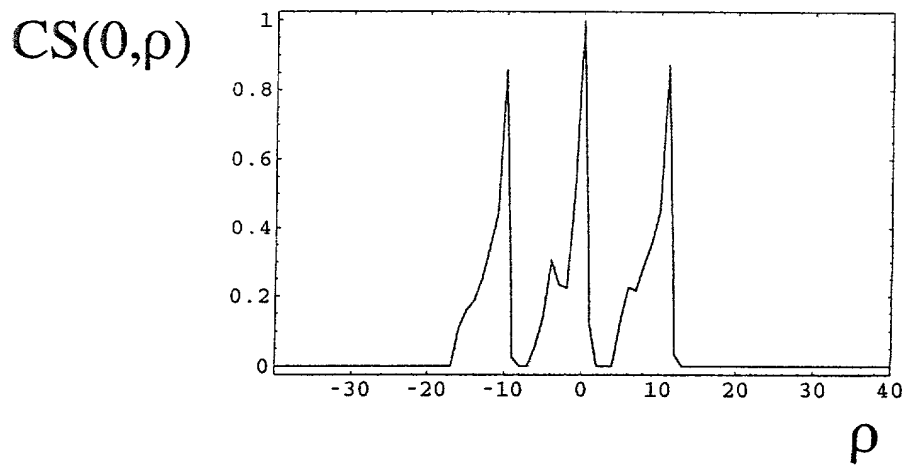


FIG. 27A

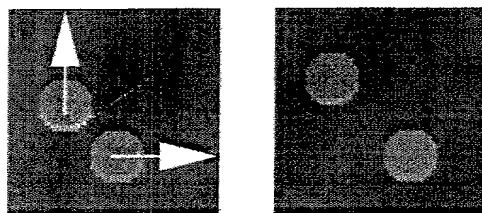


FIG. 27B

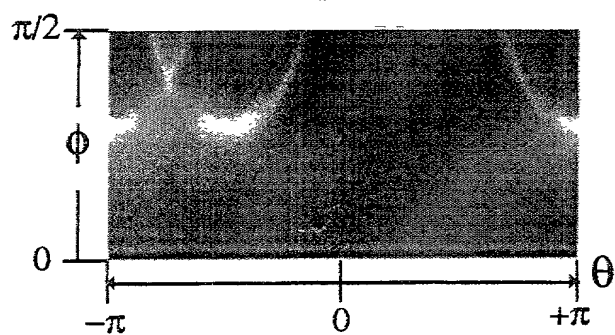


FIG. 27C

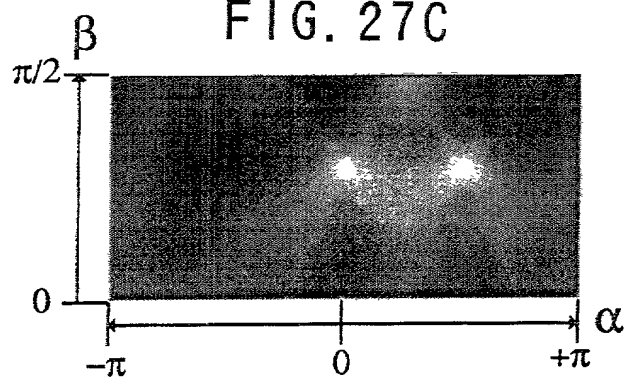


FIG. 28A

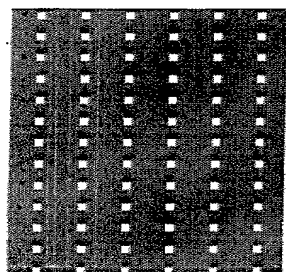


FIG. 28B

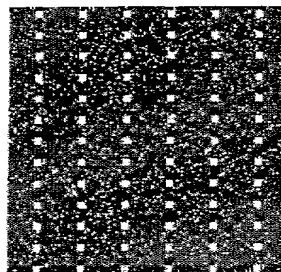


FIG. 29A

FIG. 29B

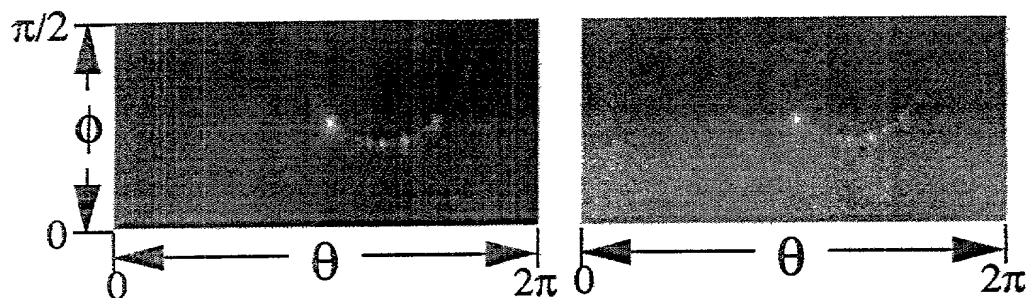


FIG. 30

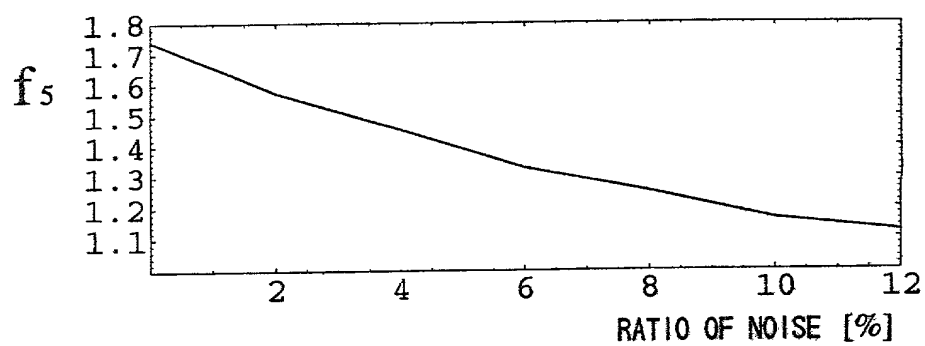


FIG. 31A

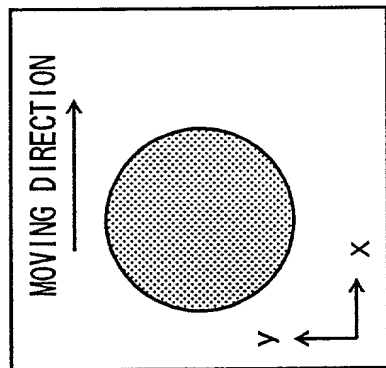


FIG. 31B

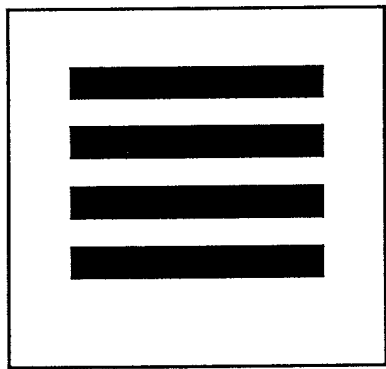


FIG. 31C

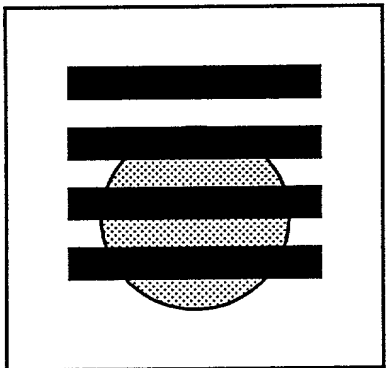


FIG. 31D

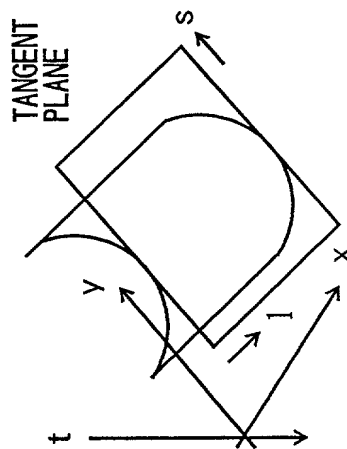


FIG. 31E

